MACHINE GUN FIRE CONTROL

By CAPTAIN GLENN P. WILHELM
Fourth U. S. Infantry

Price $2.50—*includes Sliding Rule*
Price $1.75—*for either Book or Rule*
Remit by Registered Letter, Money Order or Bank Draft

Published and For Sale by EDWARD C. McKAY
409 SWETLAND BLDG. CLEVELAND, OHIO

Machine Gun Fire Control

ERRATA SHEET

Page Eleven, Figure One

Substitute the letter "T" for "H" in "GHH", making it "GTH".

Page Fifteen

In the middle of the page following sentence containing "beaten zone varies inversely as the range" insert quotation "Small Arms Firing MANUAL".

Page Seventeen, Line Five

Change "It is always an angle of elevation" to "It is usually an angle of elevation but may sometimes be an angle of depression."

Page Twenty-three, Line Six

Change "17.7 mils" to "17.5 mils."

Page Twenty-five, Middle of Page

Change "cross cuts on the pencil every twenty inches" to "cross cuts on the pencil every inch."

Page Thirty-two, Line Fourth from Bottom of Page

Omit the word "and," substituting therefore, "as viewed from".

Pages Thirty-three to Thirty-five

Under Parallax 1, 2, 3, 4 insert the word "to" preceding the word "find" as follows: "At the Gun 'G' *to* find the angle TGP", etc.

Page Thirty-four

Omit the word "not" in the title beneath Fig. 24, making it read: "Observer on flank on line with gun."

Page Thirty-five

Insert the word "not" in the title beneath Fig. 25, making it read: "Observer not on flank on line with gun."

Page Thirty-eight, Line Twenty-one

Actual value of one mil equals 3.6 inches per 100 yards of range. Actual value of one point windage equals 4.31 inches per 100 yards of range. (See page 73 of Description and Rules for United States Rifle Cal. .30, model of 1903, revised to 1917.) One point of windage therefore equals 1.2 mils approximately or $1\frac{1}{6}$ mils. The value of $1\frac{1}{6}$ mils for one point of windage was determined experimentally. It is probable, however, that machine gun sights may be graduated to read mils instead of points and thus render any conversion unnecessary.

Page Thirty-nine, Figure Twenty-six

Change horizontal dotted line "HOH" to "AOA."

Page Forty-four, Figure Twenty-eight

Change contour elevation of "890" and "891" to "990" and "991."

Page Fifty, Line Six

Change "17¾ mils" to "17½ mils."

Page Sixty-six, Eleventh Line from Bottom

Change "1000" yards to "100" yards, making line read: "For each 100 yards of range beyond 2000 yards."

Page Seventy

Insert lines 16-17 from top of page: "In the effective zone or a total of 4. If three sight settings are".

Page Seventy-two, Second Line from Bottom

Change "index in." to "index M".

Page Seventy-five, Map Reading

Change "Map visivility" to "Map visibility."

Table Nine

Correct initial velocities as follows:

Browning Heavy	2680
Browning Light	2682
Lewis Machine Gun	2693
Marlin Aero	2706
Vickers Machine Gun	2690

On the Milometer the $1° = 17.7$ mils should be 17.5 mils. This figure 17.7 was given in text as approximate which is perfectly true. All calculations were based on the exact value of mil however.

MACHINE GUN FIRE CONTROL

PREFACE

MACHINE gun firing is a science requiring considerable mechanical ability and a thorough knowledge of ballistics. It is not the province of this text to take up the mechanical problems of the machine gunner, as that is a subject complete in itself. The study of the ballistics of the machine gun with a working knowledge of the control of machine gun fire are essential to success on the battlefield.

In order that the machine gun commander may utilize his machine guns to the best of advantage he should be capable of scientifically directing their fire on any objective or sector within the extreme limits of the trajectory.

This text was written and the fire control rule designed in order to try and teach the difficult subject of the exterior ballistics of the machine gun and to simplify to a minimum the mathematical operations in the control of fire.

The rule is not a chance design, but is the final result of numerous previous attempts to devise a rule that would render any reference to tables or penciled notes unnecessary in the field for the computation of firing data.

There is nothing official in this text and it is hoped that the methods as outlined will not be blindly followed as a drill regulation.

Machine gunners must be adaptable, as the conditions at the front are continually changing and old methods are soon rendered obsolete and scrapped.

However, a careful study of the text and a thorough knowledge of the operation of the slide rule will enable one to meet all manner of conditions and to understandingly control and direct machine gun fire under circumstances and in conformity with whatever technical methods are being used at that particular phase of the war

Knowledge and ability to make use of knowledge should be the goal of the gunner. Then, whatever may happen he can confidently follow the progress continually being made in the technique of machine gun fire and if need be, can take the initiative and work out practical methods of his own. Knowledge combined with experience will make the master machine gunner and machine gun commander.

GLENN P. WILHELM
Capt. 4th U. S. Inf.

MACHINE GUN SCHOOL
SPRINGFIELD ARMORY
SPRINGFIELD, MASS.

LIST OF FIGURES

DEFINITIONS

GENERAL INDEX

DEFINITIONS

PART I

PART II

PART III

Machine Gun

An automatic weapon firing rifle ammunition, and capable of prolonged and continuous firing. It is provided with a stable mount having a mechanical control of the barrel for motion in elevation and deflection.

Burst (of fire)

The automatic firing of a number of shots between successive releases of the firing mechanism.

Trajectory G T *Fig. 1*

The path of the bullet through the air. It is a curve resembling a modified parabola and is described by the moving bullet under the combined influences of the propelling force, the force of gravity and the air resistance.

The trajectory is assumed to be "rigid". That is, for all small angles, under about fifteen degrees, it is considered that regardless of whether the gun is fired up hill or down, the path the bullet describes through the air is not altered in shape by the change in the application of the attraction of gravity.

Drift

The lateral deviation of the bullet caused by the resistance of the air and the rotation of the bullet on its longer axis. With a right twist in the gun barrel, drift is to the right. It is caused by gyroscopic precession which is set up by the upward thrust of the air on the nose of the bullet as the rapidly rotating bullet is influenced by the attraction of gravity. This upward thrust causes the bullet (a miniature gyroscope) in resisting the thrust, to point its nose at right angles to the line of thrust.

It is probable that the thrust is first set up under the bullet by the air resistance under the nose due to the bullet keeping its long axis or nose pointed in the original direction while its trajectory or line of travel is constantly changing. At long ranges, the drift is very great due to the constantly increasing effect of the falling bullet, change of direction of its line of travel and the air resistance as it plunges its nose more and more to the side.

For long range firing with machine guns an allowance must be made for drift when using indirect fire and barrage fire as the fire control instruments, (clinometer or quadrant, etc.) give elevations

Fig. 1

TRAJECTORY

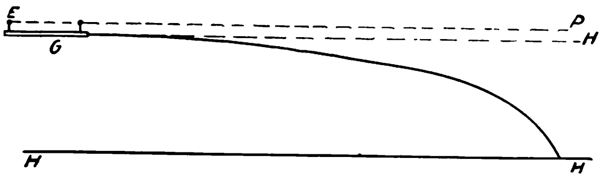
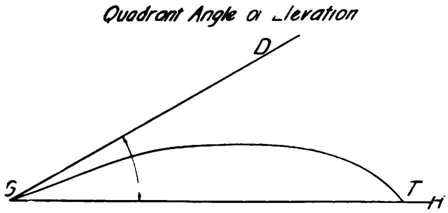


Fig. 3



When the target is on a horizontal plane through the gun

Fig. 2

ANGLE OF DEPARTURE AND FALL

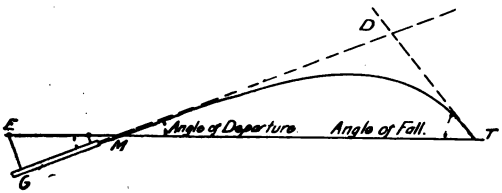
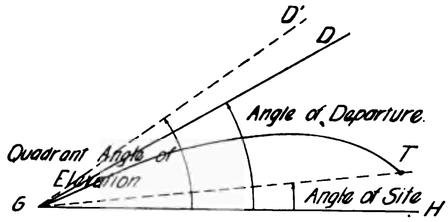


Fig. 4



When the target is above a horizontal plane through the gun

uncorrected for drift. Fire unit commanders must take this deflection into consideration when directing concentrated fire at narrow fronted targets at all long ranges.

Ordinate—Absçissa—Maximum Ordinate

The vertical distance from the horizontal plane through the gun to the trajectory curve is called the ordinate. The horizontal distance from the gun to the ordinate is called the abscissa. The greatest height of the trajectory curve is called the maximum ordinate.

Windage

The deviation of the bullet from the normal point of strike caused by the effect of the wind. It is also the amount of change made on the wind gauge.

Indirect Fire

Fire directed at a target which is usually invisible without directing the line of sight at the target.

Parallax

The apparent movement of the target or the change in the angle between the target and an aiming point other than the target, when viewed from two different positions as for instance from the position of the gun and the observer's position.

Angle of Departure D M T *Fig. 2*

The angle between the line of departure of the bullet and the line of sight.

Angle of Fall D T M *Fig. 2*

The angle between the tangent to the trajectory at the point of strike and the horizontal plane through the point of strike.

Angle of Elevation and Depression

All angles above a horizontal plane through the gun are always considered as positive and called plus. Such angles are angles of elevation.

All angles below the horizontal plane through the gun are always considered as negative and called minus. Such angles are angles of depression.

Angle of Site T G H *Fig. 4 and 5*

Angle of site is the angle between the target, gun and a horizontal plane through the gun. It may be either an angle of elevation or depression. For indirect fire it is necessary to calculate the angle of site in order to add or subtract this angle from the original angle of departure for the range from the gun to the target.

Quadrant Angle of Elevation D G H *Fig. 3*
D'G H *Fig. 4 and 5*

The quadrant elevation is the angle between the line of departure of the bullet and horizontal plane through the gun. When the target is on the horizontal plane the quadrant elevation is the same as the angle of departure. The quadrant elevation is the sum of the angle of site and the angle of departure when the target is above the horizontal, and the difference between these angles when the target is below the level of the gun.

Clinometer—Quadrant

An instrument for measuring vertical angles of elevation and depression by means of a level bubble and an adjustable graduated scale. A clinometer is called a **Quadrant** when graduated for use as a sighting device on machine guns.

Fig. 5

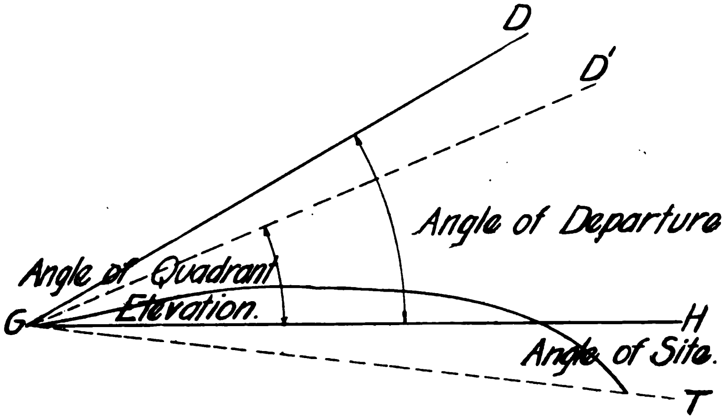


Fig. 6
DANGER ZONES

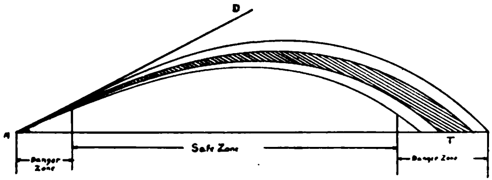


Fig. 7
BEATEN ZONES

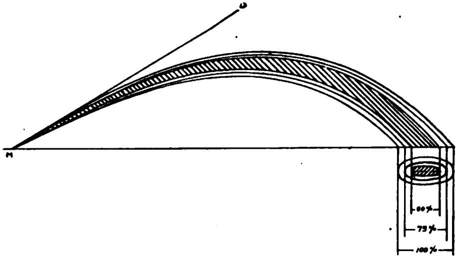
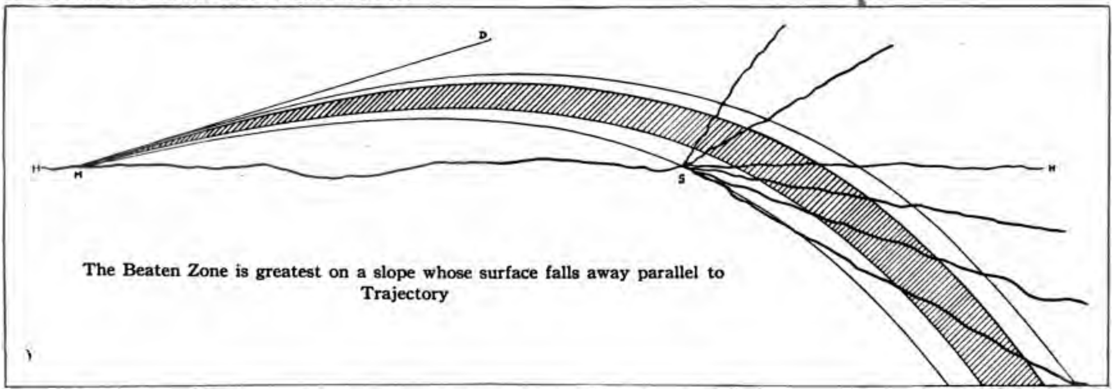


Fig. 8
RISING AND FALLING GROUND

RELATION OF GROUND TO FIRE EFFECT



The Beaten Zone is greatest on a slope whose surface falls away parallel to Trajectory

Cone of Fire or Cone of Dispersion *Fig. 6*

The figure formed in space by the trajectories of a machine gun burst directed at a single objective without altering the direction of the bore.

Beaten Zone or Machine Gun Sheaf *Fig. 7*

The intersection of the cone of dispersion with the surface on which the objective stands.

The nucleus of the shots are included in the center of the beaten zone which contains about 50% of all the shots, although in length it measures approximately ¼ of the total length.

The effective portion of the zone contains about 75% of all the shots and equals in length approximately ½ the total beaten zone.

The 100% beaten zone contains approximately all the shots of the cone of dispersion. If the cone of dispersion were cut by a plane perpendicular to the trajectory at any range, the intersection of the cone with this plane except at the longest ranges would measure less than 8 mils from the highest bullets of the sheaf to the lowest. On a horizontal surface the size of the beaten zone would depend on the range, being great for short ranges and small for long ranges. In other words the depth of the beaten zone varies inversely as the range.

The average width of the beaten zone is about 2½ mils.

The 100% zone, due to the mechanical action of the gun, cannot be greatly altered in size or shape. It can, however, be displaced. It is similar to a stream of water from a hose in that the nozzle once set, the size or shape of the stream cannot be altered by moving the nozzle about, although it can be readily displaced in any direction.

For the relation between the ground and the effect of fire see Figs. 8, 9, 10, 11, 12, and 13. In Fig. 8 it is seen that the beaten zone is greatest on a slope whose surface falls away parallel to the trajectory.

Safety Zones—Angle of Safety *Fig. 6*

The portion of the ground covered by the high part of the trajectory curve is the safety zone.

The angle of safety is the angle between the line of sight to the target and a line short of the target beyond which point the falling branch of the trajectory curve renders the ground unsafe for friendly troops.

RELATION OF GROUND TO FIRE EFFECT

Fig. 9

GRAZING FIRE

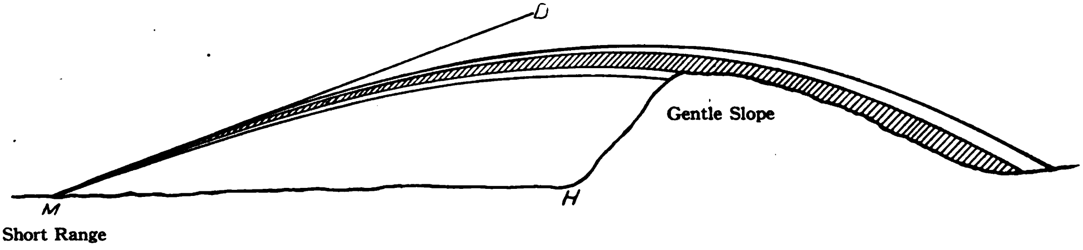
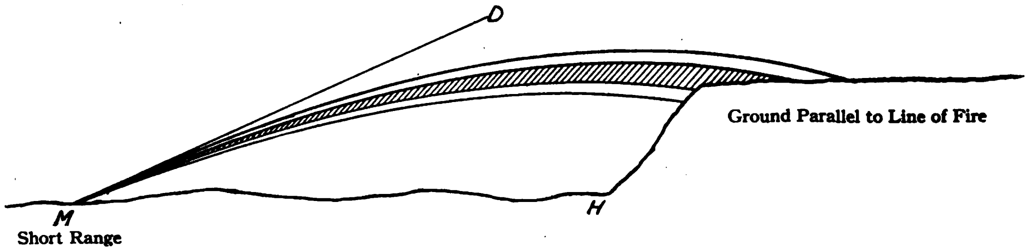


Fig. 10

GRAZING FIRE



Danger Space *Fig. 6*

The portion of the terrain adjacent to the rising and falling branches of the trajectory curve is called the danger space.

Mask, Mask Angle and Troop Angle

Mask angle is the angle between the mask (hill or object screening target from gun), gun and a horizontal plane through the gun. It is always an angle of elevation.

When firing from a contoured map the mask angle must be known in order to calculate whether the mask will be cleared by the trajectory when fire is opened on the target.

The troop angle is the angle between the advancing friendly troops, the gun, and a horizontal plane through the gun.

The troop angle must be determined in order to find whether the trajectory clears the friendly troops by a sufficient height to render over-head fire safe.

Defilade *Fig. 11*

An obstacle either natural or artificial of sufficient thickness to intercept projectiles and afford shelter from fire delivered from a given point.

Dead Space *Fig. 11*

Portions of the terrain such as folds in the ground or the reverse slope of a hill which cannot be covered with fire delivered from a given point. It is also called defiladed space.

Grazing Fire *Figs. 9 and 12*

Fire delivered over the crest of a hill with an angle of fall conforming to the slope of the ground.

Plunging Fire *Fig. 13*

Fire delivered from a height at a target situated on a horizontal plane beneath.

Fixed Fire *Fig. 14*

Fire delivered at a single point. The direction and elevation of the gun is not intentionally altered.

RELATION OF GROUND TO FIRE EFFECT

Fig. 11
DEAD SPACES

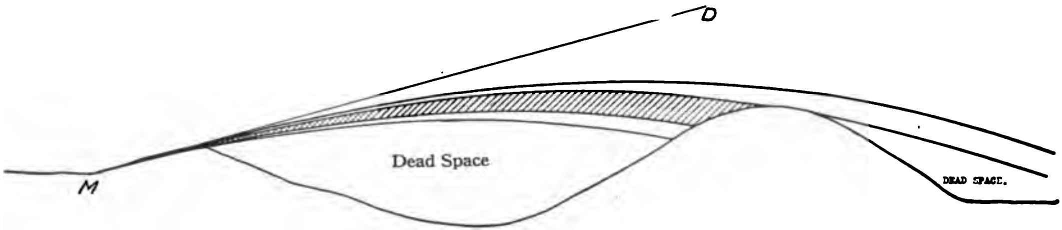
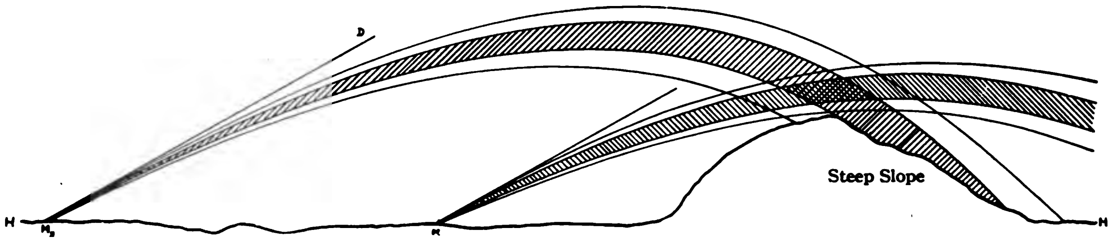


Fig. 12
SHORT AND LONG RANGES

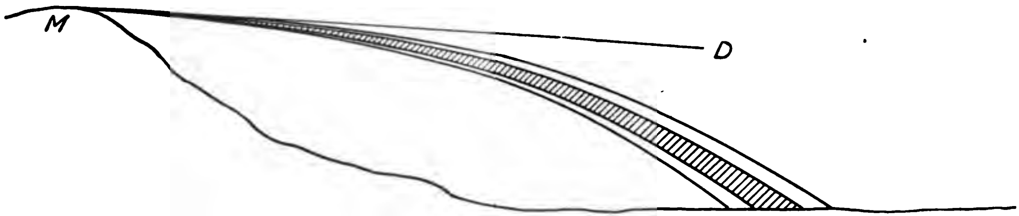


GROUND DEFILADED BY SHORT RANGE FIRE IS EFFECTIVELY COVERED BY LONG RANGE FIRE

Fig. 13

PLUNGING FIRE

RELATION OF GROUND TO FIRE EFFECT



FIRE IS INEFFECTIVE UNLESS RANGE IS CORRECT AS THE BEATEN ZONE IS TOO SMALL

Fig. 14

FIXED FIRE

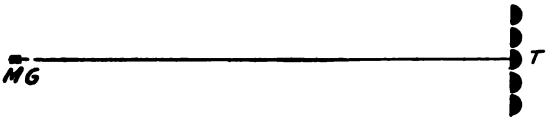


Fig. 15

DISTRIBUTED FIRE

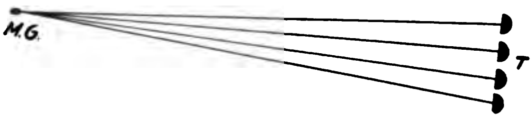


Fig. 16

SWEEPING FIRE

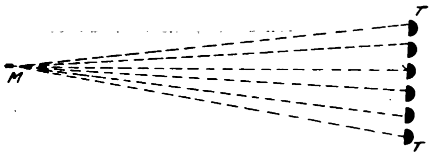


Fig. 18

ENFILADE FIRE

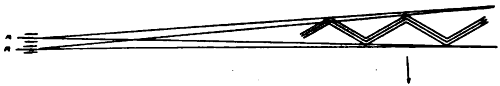


Fig. 17

SEARCHING FIRE

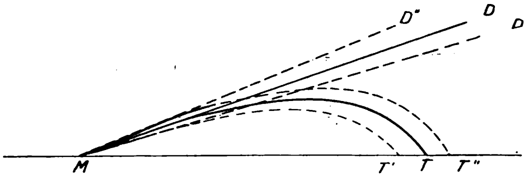
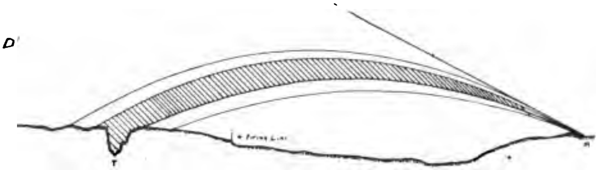


Fig. 19

OVERHEAD FIRE



Distributed Fire *Fig. 15*

Fire whose direction only is altered continually by successively taking aim at a series of lineal points.

The amount of distributed fire depends essentially on the width of the target and of the effective beaten zone. The number of aiming points used will depend upon two factors, the character of the target and the width of the effective zone.

If the width of the effective beaten zone is considered to be approximately 2½ mils, then the number of aiming points used will be the width of the target in mils divided by the width of the beaten zone in mils or:

$$\frac{W}{2\frac{1}{2}}$$

in which W is the width of the target in mils.

Each aiming point will then be 2½ mils apart. This is considering that the elements of the target have less than 2½ mils between them. If the lateral interval between the individual elements of the target exceed 2½ mils then the fire must be directed at each element in turn. The number of aiming points for each element will depend upon the width of the element just as the number of aiming points for any target depends upon its width.

Sweeping Fire *Fig. 16*

Fire whose direction is shifted rapidly without aim by swinging the gun loosely on its traversing mechanism. Used in trench warfare at close ranges for stopping assaults.

Searching Fire *Fig. 17*

Fire whose elevation, only, is altered continually by elevating and depressing the bore of the gun by means of the elevating mechanism. This is the most effective fire that can be delivered from a machine gun, providing the target is suitable, i. e., column target or enfiladed line target. See Example XIII, Part III.

Combined Sights

The device of using a series of sight settings on different guns in order to include the target in the effective beaten zone when the range is long or inaccurately determined. See Example XIII, Part III.

Enfilade Fire *Fig. 18*

Fire delivered from a point in prolongation of the target itself. For instance the flank of a line of trenches or in prolongation of an advancing line.

Machine guns using searching fire while enfilading a charging line is an example of the most effective manner of firing under the most desirable conditions.

Overhead Fire *Fig. 19*

Also called covering fire and fire of position.

Fire delivered from a vantage point in the second line over the heads of friendly troops or trenches at the enemy target.

Long Range Searching or Barrage Fire *Fig. 29*

Fire delivered at extremely long ranges over the front line trenches to search enemy lines of communication or to form a curtain of fire called a barrage.

The barrage may be laid down between the friendly trenches and the hostile trenches or laid in the rear of the enemy trenches in order to cut off the supports, etc.

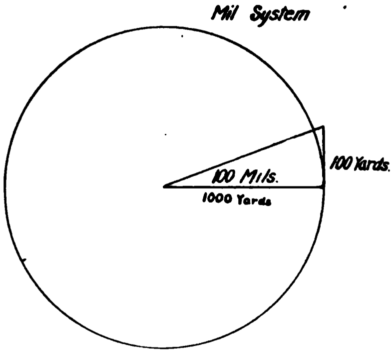
A creeping barrage is one which moves forward by time table or at a stated distance in advance of the leading elements of an attack. A barrage is usually formed by the combined fire of many guns and the firing data secured from accurately contoured maps.

PART I

THE MIL SYSTEM OF ANGULAR MEASUREMENTS

The mil is an angle subtended by one unit at a distance of one thousand such units. One inch, foot, yard or meter subtend an angle of one mil when placed at a distance of one thousand inches, feet, yards or meters.

Fig. 20



The mil is an angle whose natural tangent is .001 and equals in circular angular values 3′26.2″ (3.437′) or 17.7 mils approximately equals one degree. A minute therefore equals .291 mils or approximately ⅓ of a mil. To convert mils to minutes multiply the mils by 3.437 or for rough values multiply by 3.

To convert minutes to mils, multiply the minutes by .291 or for rough values divide by 3.

Field Artillery Mil

The exact number of mils in a complete circle would be 6283 (2 × 3.1416 × 1000). In order to facilitate measurements, the field artillery has adopted 6400 mils as the standard number of mils to the circle and have calibrated their instruments accordingly. This gives a value to the mil of 3′22.4″, which is correct for all practical purposes.

The advantages of the mil system over circular measurements for computations involving angles is that the mil system is very much simpler and requires no knowledge or application of trignometric values in order to obtain range, width or angular measurements as the mil itself is the relation between the range and width.

For instance, if one is asked: How much does 2° 53.5′ subtend at 500 yards? It would be impossible to answer without consulting a trignometric table. If, however, one is asked: How much does 50 mils subtend at 500 yards? it is a simple mental calculation to answer 25 yards; as 1 mil at 1000 yards = 1 yard (from definition) and 50 mils at 1000 yards equals 50 yards; therefore 50 mils at 500 yards must be ½ of the value at 1000 or 25 yards.

However calculations with the mil system are most easily handled by familiarity with the following equations.

From the definition of a mil, the following formulas are obtained:

Let R = Range in yards.

W = Width or height of target in yards.

M = Number of mils subtended by W.

$R \times M = 1000 \times W$, or $RM = 1000\ W$.

Transposing,

$$R = \frac{1000\ W}{M}$$

$$M = \frac{1000\ W}{R}$$

$$W = \frac{RM}{1000}$$

Note that to get either range or mils the width is multiplied by 1000 which is divided by the other known quantity, while to get width, it is the product of the two known quantities divided by 1000.

In case these three equations become confused, memorize the single equation $RM = 1000\ W$ and then by transposition secure the one you wish.

The Mil Rule

A mil rule is a scale, having graduations W, which subtend angular values M, if the scale is held at a distance R from the eye.

To calculate the graduations of any rule select the values of R in inches and M in mils, and solve the equation for W in inches.

Example. Select R as 20 inches and M as 50 mils as the graduation you wish on the rule. To find W substitute as follows:

$RM = 1000\ W.$

Transposing,

$$W = \frac{R\,M}{1000}$$

Substituting,

$$W = \frac{20 \times 50}{1000} = 1 \text{ inch.}$$

Therefore every inch on the mil rule is equal to 50 mils. Each tenth of an inch will therefore equal 5 mils. These are the most convenient dimensions to use with inches as this rule will perform a dual function, being both a mil rule and a scale of inches and tenths inches.

For the metric system the most convenient rule is one graduated in millimeters with a string ½ meter long. Each millimeter will then represent two mils and every 25 millimeters, 50 mils, etc.

The simplest form of mil rule that can be fashioned would be one made up of a 20-inch string and a lead pencil with cross-cuts on the pencil every 20 inches to represent units of 50 mils.

The practical uses of a mil rule are as follows:

I. Determination of Height or Width.

From a map or a range finder the distance to the tower of an old ruin has been found, from an observation point in rear of the firing line or fire trench to be 1500 yards.

How high is the tower?

Upon measuring the angle in mils, subtended by the tower, it is found to be 10 mils high.

By substitution in $W\ (H) = \frac{R\,M}{1000}$

$$W = \frac{1500 \times 10}{1000} = 15 \text{ yards or 45 feet high.}$$

Note. This same method can be applied to a length of trench or a distance between any two objects which can later be used to range upon.

II. Determination of Range.

Enemy machine guns are known to be adjacent to the tower of an old ruin. What is the range to the hostile position, knowing

the height of the tower to be 45 feet (15 yards) as previously determined from an observation point in the rear?

Upon measuring the angle in mils subtended by the tower it is found to be 150 mils high.

Therefore,

$$R = \frac{1000\ W}{M}$$

Substituting,

$$R = \frac{1000 \times 45}{150} = 300 \text{ yards.}$$

Note. The range can always be determined direct from a known height or width. The dimensions of familiar objects such as distances between trolley poles, etc., can always be utilized thus.

Estimation of the height or width of objects as a means to determine a range is not advocated as it has been found by experience to be inaccurate since it introduces two errors in the result, the first error being the original estimation and the other the taking of the mil reading. In such cases it is best to estimate the range direct, thereby eliminating the error in the mil reading.

Where the initial range to an objective is known, a width or height should be calculated for use further up as the range finder may not then be available.

After the width of the target has been determined, as the firing line advances it is necessary to make but one mil reading for each halt and immediately secure that range by dividing 1000 times the width by the mil reading, which is readily done.

Example. The flanks of an enemy position are seen to subtend 90 mils when the firing line begins to deploy at a known range of 1300 yards as determined by the B. and L. range finder.

Hence the width of the enemy position in yards is:

$$W = \frac{R\,M}{1000};\ W = \frac{1300 \times 90}{1000} = 117 \text{ yards.}$$

As the line moves forward and the method of original determination of the range being unavailable, it is found at the first halt that the hostile position now subtends 100 mils.

What is the new range?

$$R = \frac{1000\ W}{M} = \frac{1000 \times 117}{100} = 1170 \text{ yards.}$$

At the next halt the reading is 120 mils. What is the range?

$$R = \frac{117000}{120} = 975 \text{ yards.}$$

At the next halt a reading of 130 mils would be 900 yards and likewise a reading of 200 mils would be 585 yards.

Regardless of the number of halts the range is always immediately obtained by using $1000 \times W$ as a constant as long as the same width is used, and dividing by the mil reading.

III. Determination of Range where the height or width is unknown.

It is not necessary to know either the height or width of a target in order to calculate a range providing that a distance forward or backward from the position of the observer can either be paced or measured.

This range finding method is as follows:

1. Read the number of mils from the observer's position that the target subtends. Call this first reading M_1.

2. Go forward or backward a certain known distance. Call this distance D.

3. Read the number of mils subtended by the target from the observer's new position. Call this second reading M_2.

Substitute M_1; D and M_2 in the following formula which is derived from the previous ones by factoring and eliminating W.

Range = Distance of advance or retirement times the second mil reading; divided by the difference between the two mil readings, or,

$$R = \frac{D\,M_2}{\text{Diff. between } M_1 \text{ and } M_2}$$

Example. From an observation point in the second line a hostile trench is found to measure 150 mils.

On advancing 200 yards it is found to measure 200 mils. What is the range?

$$R = \frac{D\,M_2}{\text{Diff. in mils}} = \frac{200 \times 150}{50} = 600 \text{ yards.}$$

Note. Regardless of which way the base D is measured, whether away from or towards the object, the numerator of the fraction is always the product of the last two operations performed i. e. measuring or pacing D and taking the second mil reading; while

the denominator is always the difference between the two mil readings.

IV. Determination of angles in mils.

From a map, the distance occupied by the enemy trenches on a reverse slope of a hill is scaled as 300 yards. The range scales 1800 yards. What is the angle in mils subtended by the enemy trenches?

$$M = \frac{1000\ W}{R}$$

Substituting,

$$M = \frac{1000 \times 300}{1800} = 166 \text{ mils.}$$

V. Determination of angular movements in mils of the elevating and traversing mechanism of machine gun mounts.

While the graduations on any scale, upon which measurements can be taken are easily calculated into mils, it will be found that the easiest way to get at the amount in mils, made by the various movements of the traversing and elevating mechanism on machine gun mounts is as follows:

Set machine gun on mount with center of motion (axis about which gun pivots) 1000 inches ($27\frac{7}{9}$ yds.) from a wall.

Determine the number of inches on the wall that one turn of the elevating wheel or traversing wheel will throw the line of sight on the wall.

The angle in mils will then be equal to the number of inches the line of sight has moved.

It is best to clamp a telescopic sight or a field glass to the gun in order to get a finer sight to points on the wall.

In the same manner, tripods can be calibrated using the metric system. A convenient measure will be 10 meters (1000 centimeters) to the wall and the change in the line of sight measured in centimeters. Each centimeter will then be 1 mil.

The most accurate determination will be made if a number of turns of the hand wheel is made and the total number of mils the line of sight is shifted is divided by the number of turns of the wheel in order to get at the value of one turn.

A good machine gunner should know the angle in mils that the front sight of his gun subtends, both vertically and horizontally. Any other measurements that are convenient, such as the width of the sight cover, etc., should also be obtained.

The mil system is the most adaptable system of calculating angular values. It is applicable to any unit of any system, whether metric or English.

Mil calculations are readily calculated mentally, but the computations are more rapidly and accurately performed by employing the Milometer—thus eliminating mental effort and errors.

PART II

INDIRECT FIRING

Indirect fire with machine guns is the practice of firing at a target while using a different sight setting and a different aiming point than is offered by the objective itself. The target may or may not be visible to the gunner. Over-head fire (i. e. firing over friendly troops), night firing and firing with the use of auxiliary aiming points are various methods of employing indirect fire.

As to the **practicability of indirect fire,** a well-known British authority* says in part as follows:

"Experience of machine gun work in the entrenchment battles of the Western front shows that whatever may have been written on the subject before the war, there are plenty of means of using the guns at even the *longest ranges* in this new kind of fire.

The use of the guns at longer ranges is for covering fire over the heads of the infantry they are supporting, or directed against the enemy supports and the lines by which he is bringing up his re-enforcements to the fighting line.

There certainly will be occasions when the long range fire of the machine gun may be usefully employed. In discussing machine gun tactics in the entrenchment battle, we have described methods by which this kind of fire has been effectually used at ranges up to 2800 yards.

The special conditions of the entrenchment battle, the thorough mapping of the ground and the accumulated results of aerial reconnaissance, make this kind of fire easier to employ than it will be in battles in the open.

There are two kinds of machine gun tactics. The tactics of long range, rendered possible by the conditions of the entrenchment battle, and the tactics of medium and short ranges which have their place in the manoeuvre battle in the open, and the assault during the entrenchment battle.

---

* "Longstaff and Atteridge."

The special conditions that render long range fire practicable and effective are these. In the entrenchment battle prolonged not only over days, but it may be over weeks, the enemy's position is fixed and easily defined. More than this, systematic aerial reconnaissance day after day renders it possible not merely to fix the general position and limits of the hostile position, but also to map out most accurately the position of the advanced trenches which form his firing line, the trenches farther back where he keeps his supports and reserves, and the lines by which these supports and all supplies of ammunition must be brought up to the advanced trench. These lines being the communication trenches, not only is the enemy's firing line permanently fixed to a defined position, but all movements immediately in rear of it must necessarily follow clearly fixed lines.

During the long preparation for an attack upon the enemy, all these positions and lines of communication can be accurately laid down, if large scale maps of the ground he holds are available.

In the warfare on the Western front these maps, elaborately contoured at short vertical intervals, are available, and this not only facilitates the mapping of the enemy's position, but also makes it perfectly easy to work out rapidly accurate sections of the ground on any line of fire to its front. It is, therefore, possible to select a machine-gun position in our own lines, or in rear of them, from which, by indirect fire, selecting the appropriate range and trajectory, the bullet sheaf from the guns will clear the intervening obstacles and descend upon a given spot in the enemy's lines. That the bullets will strike the selected patch of ground in the enemy's position is not a matter of chance, but of absolute certainty.

Reserve trenches will often be placed in rear of the crest of a slope of ground. In such a case we will find the communication trenches running back by the reverse slope of the rise in the ground to support trenches in rear of and hidden by it. In such a case it will often be possible to select a machine gun position that will give a trajectory which will sweep the reverse slope. It is obvious that the longer the range the more chance there is of selecting lines of trench that are open to enfilade. In the entrenchment battle the advanced trenches on both sides are fairly near each other at the outset. By using the longer ranges of his weapon, the machine gunner with his guns in position behind the advanced lines can pick out lines of trench far away to right or left, on which

he can bring a diagonal indirect fire, sometimes enfilading a considerable length of trench."

The advantages of indirect fire over direct fire are:

1. Screened from direct hostile fire.
2. Produces feeling of security and confidence on crew.
3. Fire is mechanical as crew is calm.
4. Company may come into action unobserved and under cover.
5. Simplifies supply of ammunition.
6. Position of guns may often be changed unknown to the enemy.
7. Flash of guns at night concealed by mask from the enemy.
8. Good line of retirement in withdrawal actions.

Indirect fire has the following disadvantages:

1. Slowness.
2. Requires skill to be effective.
3. The ground in the immediate front of the mask is not covered by the guns firing over the mask, thus creating a dead space that must be covered by other guns.
4. Moving targets can not be covered readily by indirect fire.

Machine guns are being multiplied in numbers in all armies. Now that there are many of them the rule is to divide the force, put some machine guns into action at once and hold the others in reserve for a while, to be sent up as the firing line is reinforced, or to be pushed forward to bring a storm of concentrated fire to bear as ordered.

Machine guns are not artillery, but are condensed infantry fire. The reserve of machine guns do not represent fire power left idle, but they should be classed with the infantry supports and reserves kept in hand to be used to reinforce and carry forward the firing line."

The principles upon which indirect fire is based are that the direction and elevation of the piece are absolutely independent of the sighting. Thus there is only one position in which the bore of a gun may be pointed in such a manner that upon the piece being fired, the shots will strike the target.

However, there are an infinite number of positions in which the sight may be placed in order that the bore may be correctly pointed and after the gun is properly laid the sights may be shifted up to the limit of their capacity and thus utilize any convenient aiming point within the radius of their action.

However, in order to lay the piece properly two things must be determined.

1st. Deflection or direction.

2nd. Elevation.

The deflection or direction is usually determined by:

1. Eye.
2. Instruments (compass)
3. Parallax and mil scale.

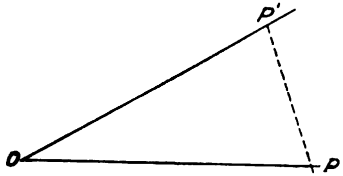
The elevation is usually determined by the reading of the necessary vertical angles and a table of elevations or their equivalent.

The elevation necessary to place on the gun is generally computed from a level aiming point in the horizontal plane through the gun. This point is located easily with a pocket level placed on the gun. A horizontal plane is thus always determined and if a more convenient aiming point is desired, the necessary data for its use is readily calculated from the horizontal plane.

Both the direction of the gun and its elevation for indirect fire are determined more or less approximately and the fire corrected by an observer who is stationed at any place within signaling distance of the gun position. The observer is equipped with a range finder and such equipment as may be best utilized for obtaining ranges and angles."

Fig. 21

PARALLAX



P = First position.
P' = Second position.
O = Object.
Parallax = POP'.

Parallax

Parallax is the apparent movement of an object when viewed from two different positions. It is the angle subtended by the distance between the two positions and the object.

For indirect fire with machine guns parallax is applied to the apparent change in the position of the aiming point when viewed from the gun and from the location of the observer. This apparent

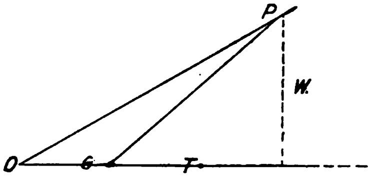
change is the angle of parallax, and in order to give the proper deflection to the gun for the aiming point, the angle of parallax must be determined first, after which the angle of deflection can be calculated.

Parallax

Let O = Position of observer.
G = Position of gun.
T = Position of target.
P = Position of aiming point.
W = Width (yards) between P and line of fire.

I. When the observer is in the rear of the gun.

Fig. 22
PARALLAX



OBSERVER IN REAR OF GUN

Known values are:

Distance O G and O P and angle T O P.

At the gun G find the angle T G P between the target T and aiming point P.

From the known distance O P and measured angle T O P (mils) calculate the width W (yards).

For small angles such as at O, G P = O P — O G (approximately).

Knowing G P and W, angle T G P in mils is computed.

Example.

O P = 1700 yards. O G = 300 yards.

Angle T O P = 10 mils.

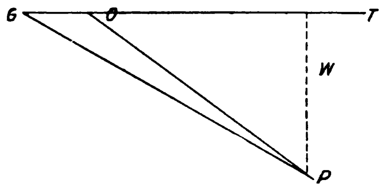
$$\text{Then } W = \frac{1700 \times 10}{1000} = 17 \text{ yards.}$$

And

$$\text{Angle } T\,G\,P = \frac{17 \times 1000}{1400} = 12 \text{ mils.}$$

II. When the observer is in the front of the gun.

Fig. 23
PARALLAX



OBSERVER IN FRONT OF GUN

Known values are distance G O and O P and angle T O P.

At the gun G, find the angle T G P between the target T and the aiming point P.

Measure W in mils from O.

Knowing O P and W (mils) calculate W in yards.

Knowing W yards and G P yards (G O+O P) find W (angle T G P) in mils from G.

Example

O P = 1400 yards. O G = 400 yards.

Angle T O P = 20 mils.

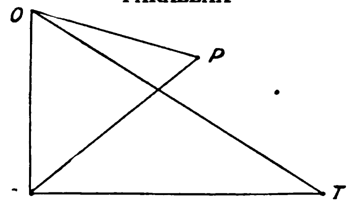
$$W = \frac{1400 \times 20}{1000} = 28 \text{ yards.}$$

Therefore,

$$\text{Angle } T\,G\,P = \frac{1000 \times 28}{1800} = 16 \text{ mils.}$$

III. When the observer is on a flank on line with the gun.

Fig. 24
PARALLAX



OBSERVER ON FLANK NOT ON LINE WITH GUN

The known values are the distances O P; O T and O G and the angle T O P.

At the gun position G, find the angle T G P.

Assuming that T G = T O and G P = G O; from P O and O G calculate the angle G P O in mils.

Knowing T O and G O calculate angle G T O in mils.

The sum of the angles G T O and T G P = the sum of the angles G P O and T O P.

(Vertical angles, etc.)

Hence angle T G P = angle G P O + angle T O P — angle G T O.

Example. O P = 3000 yards. O T = 2200 yards. O G = 80 yards. Angle T O P = 20 mils.

Then

$$\text{Angle } G P O = \frac{1000 \times 80}{3000} = 27 \text{ mils.}$$

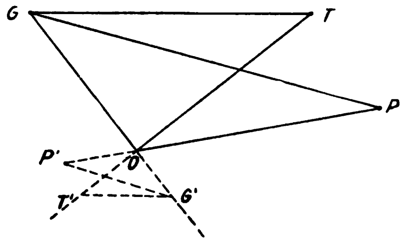
$$\text{Angle } G T O = \frac{1000 \times 80}{2200} = 37 \text{ mils.}$$

Hence Angle T G P = 20 + 27 — 37 = 10 mils.

IV. When the observer is on a flank but not on line with the gun.

Fig. 25

PARALLAX



OBSERVER ON FLANK ON LINE WITH GUN

The known values are the distances O P, O T, O G and the angle T O P.

At the gun position G, find the angle T G P.

Let 1 ft. = 100 yards and lay off O P′ = O P locating a point P′ in line with O and P.

Likewise locate G′ and T′ so that O G′ = O G in prolongation of G O and so that O T′ = O T in prolongation of T O.

The observer at G′ actually measures on the ground, angle T′G′P′ which equals angle T G P.

Angle T′G′P′ may also be determined as follows:

The observer measures the angles O P′G′ and O T′G′.

Angle T O P = T′O P′.

Then angle T G P = angle T O P + angle O P′G′ — angle O T′G′.

Note that this method of determining the horizontal angle between the target and any aiming point may be determined with the observer in any position he may assume.

Methods of indirect firing are enumerated in the following table:

Methods of Indirect Fire

I. Observation.
- A. Estimation.
- B. Mil scale.

II. Distant points nearly vertically above the target.
- A. Graticule or inverted sight.
- B. Methods by use of mil system.

III. Level bubble.

IV. Method by use of quadrant elevation where gun and target are not on the same approximate level.
- A. By determination of vertical angles where the observer is in front of gun.
- B. By determination of vertical angles where the observer is in rear of the gun.

V. Indirect fire from a map.
- A. Quadrant elevation.
- B. Natural aiming point.

Indirect Fire

I. Observation.

Under favorable circumstances where the target and strike of the bullets are readily seen, indirect fire may be directed by the same means as direct fire.

A. By estimation.

Find the range and lay the gun with the line of sight directed as nearly as possible toward the target.

Fire a burst for observation and by estimating the shorts and overs correct the sight setting accordingly. When on the target, clamp the gun and run the sight up or down until a good natural aiming mark is found or a suitable artificial one prepared.

B. Proceed as in A, except that instead of estimating the shorts or overs, correct the sight setting by the use of the mil scale or inverted sight leaf scale.

II. Distant points nearly vertically above target.

A. Method for graticule card (string and card graduated similarly to rear sight leaf) type EE field glass fitted with graduations similarly to rear sight leaf, or string with an inverted sight leaf held at sight base (22⅛″) from eye.

Procedure.

a. Determine range to target.

b. From position in rear of gun not over six feet above it sight at the target with the scale aligning the graduation on the scale corresponding to the true range, on the target.

Note. True range on target.

c. Choose any aiming mark vertically or nearly so above the target and note what graduation of the scale cuts the aiming mark.

This graduation is the correct sight setting to use while firing at the target and aiming at the mark.

Example. Range 800 yards. Set 800 yard line of scale on target. Without moving scale note that spot caused by shell crater on side of hill above target is cut by 300 yard line. A sight setting of 300 yards with gun aimed at crater will hit the target 800 yards distant.

B. Methods by use of mil system.

Procedure.

a. Proceed as for graticules except that the vertical interval between the target and aiming mark is measured on the mil rule.

b. Subtract this reading from the angle of departure in mils (see table in back of book) for the correct range.

c. Set the sights at the range whose angle of departure in mils is equal to this remainder.

Example.

a. Range 800 yards. Vertical interval between target and aiming point 7 mils.

b. From the table the angle of departure for 800 yards is 9.3 mils. 9.3 mils less 7 mils = 2.3 mils.

c. Range whose angle of departure equals 2.3 mils is seen from the table to be 300 yards which is the correct sight setting to use.

The following method can be used on all machine guns having a rear sight with an elevating screw head one complete turn of which equals 1 mil. (Benet Mercie—Maxim—Vickers—Colt, etc.)

After obtaining the mil reading as above and having set the sights at the correct range to the target, screw down the elevating screw head as many complete turns as there are mils in the reading. It is obvious that the sights are then set at the correct range.

Another method applicable to a tripod which has a slow vertical motion that can be determined in mils follows:

Benet Mercie. One turn of hand-wheel equals 16 mils, ⅛ turn = 2 mils.

After having secured the mil reading set the sights to the true range and aim at the aiming point. Lower line of sight as many ⅛ turns as two is contained in the mil reading. Without disturbing the laying of the gun run the sights down until the aiming point can be seen again.

Note. In all the foregoing examples it is assumed that the aiming point is practically above the target. If it is to one side, measure the horizontal interval between the target and the aiming point in mils and take windage in the opposite direction allowing 1⅛ mils for every point of windage.

This deflection may be determined with the gun by first aiming at a point above the target with zero windage and then taking enough windage in the opposite direction until looking through the sights the aiming point can be seen. The gun must not be moved, however, while doing this.

III. Method by use of pocket level bubble.

Gun and target must be approximately on the same level.

a. Determine range to the target.

b. Level the gun and with zero sight setting or by looking through the bore select or locate a level point 25 or more yards in front.

c. Reset the sights to the range to the target, aim at the level point and the gun is correctly set for the target.

Note. The aiming point can be aligned on the target by an officer standing in rear of the gun or by any one of the methods of parallax.

IV. Method by use of quadrant elevations where gun and target are not on the same approximate level.

The direction to the target when the target is marked can always actually be determined on the ground by aiming in a row of stakes

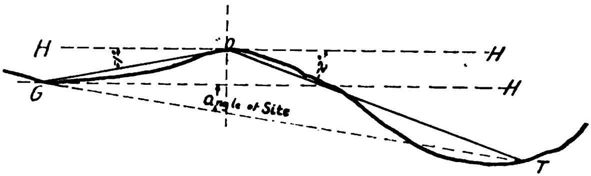
from gun to target or the deflection to the aiming point can be determined by the aid of an observer using the most suitable parallax method.

The elevation to use on the gun for any aiming point is always determined by subtracting the angle of site from the angle of departure when the aiming point is above the target and adding it when below it, because to hit the target which is not on the same level with the gun it is first necessary to elevate the gun to the correct angle to carry the bullets to the full range to the target if it were on a horizontal plane. If it is above, an additional angle must be added to the full range (angle of departure) and if it is below this angle must be subtracted. This angle is the angle of site previously mentioned.

In practice in the field where a map is not available the aiming point selected is usually a level one but any aiming point may be used that is suitable.

The angle of departure is obtained from the tables in the back of the book but the angle of site must be obtained in the field by actually measuring the vertical angles and calculating the resulting angle from the following formula:

Fig. 26
QUADRANT ELEVATION
OBSERVER IN FRONT OF GUN



In the figure: G = position of the gun; T = target and O = the position of the observer.

Then O T = distance from observer to target.

O G = distance from observer to gun.

G T = Range (i. e., distance from gun to target.)

Let A = angle of site. A O T = angle from observer, the target and a horizontal plane through the observer. A O G = angle from the observer, the gun and a horizontal plane through the observer.

Then $A = \dfrac{(O\,T \times A\,O\,T) - (O\,G \times A\,O\,G)}{G\,T}$ in degrees, minutes or or mils, depending upon which unit is chosen.

This formula is derived from the fact that the tangents of small angles are *directly* proportional to their angles.

A. Procedure for indirect fire by this method. Observer between gun and target.

a. Select location of gun.

b. Send observer forward to locate aiming point, read angles plus or minus to gun (A O G) and to target (A O T) from his position on the mask and to get distances to gun (O G) and to target O T.

Note angles A O G and A O T will be plus or minus, depending upon whether they are above or below the observer's position.

c. Multiply each angle by its corresponding distance and divide the algebraic difference by the total range as illustrated by formula. This will give the angle of site.

d. Add (or subtract) the angle of site to the angle of departure for the range and look up the range whose angle of departure corresponds to the result.

e. Level the gun with the sights set at zero on a level aiming point, and raise the sights to the range found above. Then relay the gun on the level aiming point again with the elevation set off on the sight. This will elevate the gun for the target.

Example. Range G T = 1300. O G = 500. O T = 800.
Observer's angle to gun A O G = —1° = —60′ = —18 mils.
Observer angle to target A O T = —2° = —120′ = —35.5 mils.
What is angle of site H G T in minutes? In mils?

Minutes: Substitute values in formula

$$A = \frac{(800 \times -120) - (500 \times -60)}{1300} = \frac{(-96{,}600) - (-30{,}000)}{1300}$$

Note. Minus a negative 30,000 changes the minus to plus.

$$= \frac{-96{,}000 + 30{,}000}{1300} = \frac{-66{,}000}{1300} = -51 \text{ minutes approx.}$$

Mils: Substitute values in formula.

$$A = \frac{(800 \times -35.5) - (500 \times -18)}{1300} = \frac{(-28{,}400) - (-9{,}000)}{1300}$$

$$= \frac{-28{,}400 + 9{,}000}{1300} = \frac{19{,}400}{1300} = -15. \text{ mils. approx.}$$

The correct sight setting for a level aiming point using either minutes or mils will be:

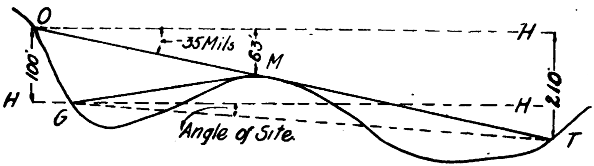
	Minutes	Mils
Angle of departure for 1300 yards	80	23
Angle of site	—51	—15
New range whose angle of departure is approx. 750 yards.	29 min. or	8 mils is

Note that on any machine gun having a rear sight with an elevating screw head one turn of which is equivalent to so many mils, tables of elevation are unnecessary.

For instance, on the Vickers one turn of elevating screw head is one mil. If then, in the foregoing problem the sight is set at 1300 yards (angle of departure) and the sight is screwed down 15 complete turns of the elevating screw head, it will automatically subtract the angle of site and leave the sight set in readiness at the correct range for opening fire. Of course, if the target is higher than the gun, the sight would be screwed up instead of down.

B. By determination of the vertical angles where the observer is in the rear of the gun.

Fig. 27
QUADRANT ELEVATION
OBSERVER IN REAR OF GUN



O M = 600. O T = 2000. G is 100′ below O and the horizontal distance between G and O is 100 yards.

Angle T O H = —35 mils = angle M O H.

$$W = \frac{RM}{1000} = \frac{600 \times -35}{1000} = -21 \text{ yards} = -63 \text{ ft.}$$

and

$$W = \frac{RM}{1000} = \frac{2000 \times -35}{1000} = -70 \text{ yards} = -210 \text{ ft.}$$

Therefore M is 63′ below O and T is 210′ below O as above.

Thus M is 37′ above G; since G is 100′ below O while M is 63′ below O, and T is 110′ below G; since G is 100′ below O while T is 210′ below O.

Also the mask angle measured from the gun is:

$$M = \frac{1000\ W}{R} = \frac{1000 \times 12}{500} = 24 \text{ mils.}$$

And angle of site is:

$$M = \frac{1000\ W}{R} = \frac{1000 \times -37}{1900} = -19.5 \text{ mils.}$$

The angle corresponding to the range would be the angle of departure for 1900 yards less the angle of site or:

50.5 mils—19.5 mils or 31 mils approximately.

The sight setting to correspond to an angle of departure of 31 mils is 1500 yards.

This is the correct sight setting to use with the aiming point on a level with the gun or in other words the quadrant elevation.

If it is desired to use as an aiming point a convenient point on the slope or crest of the hill forming the mask, proceed as follows:

Subtract from the quadrant elevation of 31 mils the vertical angular difference between the horizontal plane and the aiming point.

In this problem the vertical angular difference between the horizontal plane and the aiming point, if taken as the crest of the hill equals 24 mils.

31 mils minus 24 mils = 7 mils.

Therefore with the sights set at a range corresponding to 7 mils or 650 yards, the crest of the mask or hill or a point on the crest, can be taken as the aiming point and fire opened on the target.

If an aiming point higher than 31 mils were chosen it could not be used as it would result in a negative setting of the rear sight leaf.

With a clinometer, this, of course could be done,

Gun is at G_1, Target at T.

Range scales 1000 yards. The line of fire passes over the crest of the hill (mask) at 400 yards, contours show elevation of gun as 1000′, mask as 1012′, and target as 991′, therefore mask is 4 yards above G_1, the target is 3 yards below G_1 and the:

$$\text{Mask angle} = \frac{1000\ W}{R} = \frac{1000 \times 4}{400} = +10 \text{ mils.}$$

$$\text{Angle of site} = \frac{1000\ W}{R} = \frac{1000 \times 3}{1000} = -3 \text{ mils.}$$

The sight setting necessary to *hit* the crest of the mask and the sight setting to *clear* the mask are approximately identical.

Therefore the sight setting to clear the mask is the angle of departure plus angle to mask or:

Angle of departure 400 yards	=	3.4 mils.
Angle to mask	=	+10 mils.

Then the range whose angle of departure = 13.4 mils is 975 yards.

Therefore the sight setting to clear the mask is 975 yards.

The sight setting necessary to hit the target is calculated in a similar manner from the range and angle of site to be 880 yards.

Since it takes 975 yards elevation to clear the top of the hill and only 880 yards to hit the target it is obvious that to fire on the target over the hill from the present gun position is impossible.

Move the gun 300 yards to the rear to G_2.

The gun is now 1300 yards from the target, 700 yards from the hill and 900 yards from the friendly troops in the firing line at F. L.

The contours show the gun to be 2 yards below the mask, 6 yards above the troops and 5 yards above the target.

Therefore the:

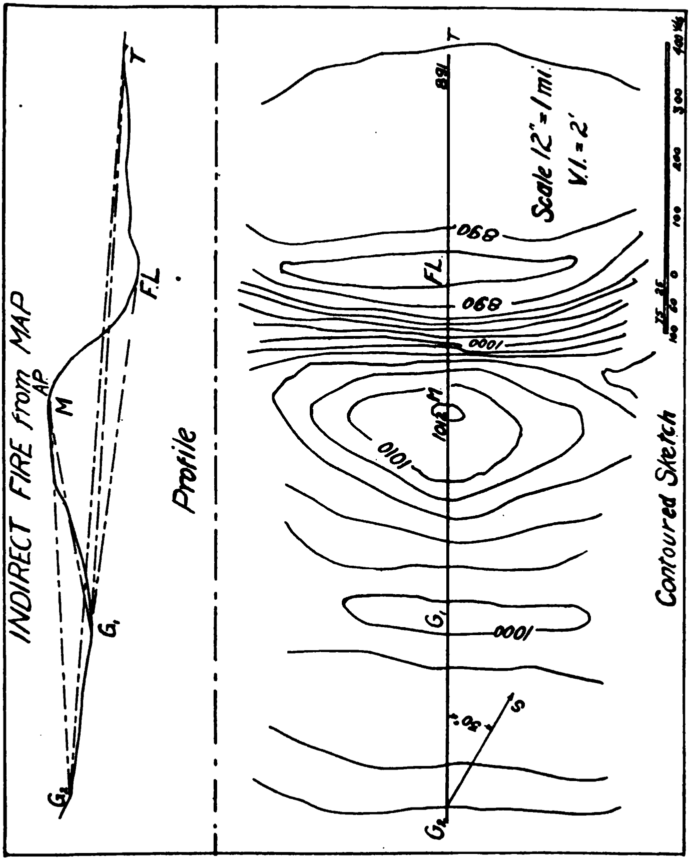
$$\left.\begin{array}{r}\text{Mask angle} = +3 \text{ mils}\\ \text{Angle of site} = -3 \text{ mils}\end{array}\right\}\text{approx.}$$

Troop angle = —6½ mils.

The mask trajectory is therefore 850 yards, the target trajectory 1180 yards while the trajectory necessary to hit troops at F. L. is 500 yards.

The 1180 yard trajectory for the target will easily clear the hill which has an 850 yard trajectory for its crest.

Fig. 28


INDIRECT FIRE from MAP
Profile
Contoured Sketch
Scale 12" = 1 mi.
V.I. = 2'
T
F.L.
A.P.
M
G1
G2
S
890
1000
1010
1012
891
30°

*Is it safe to fire over the troops at F. L. neglecting the defilade of the mask?

Overhead fire is generally considered safe when the lowest bullets of the machine gun sheaf clears the friendly troops by an angle of 1 degree or 17¾ mils. The lower half of the 100% zone (which contains all bullets of the machine gun sheaf below the theoretical center of the sheaf or actual trajectory) rarely exceeds 3¾ mils.

Allowing 3¾ mils as the vertical angle between the lowest bullets of the sheaf and the center of the sheaf or actual trajectory and adding 17¾ mils as a factor of safety gives 21 mils as the necessary safety angle between the friendly troops over which the fire is being directed and the lowest flying bullets of that sheaf.

Following this system, fire can not be directed over the troops for:

Angle of departure of trajectory to troops	= 5 mil approx.
Safety angle	=21 mils approx.

Angle of departure for range to be considered safe = 26 mils.

This is the angle of departure for a range of 1375 yards and is a greater range than is being used i. e. 1180 yards.

Considering the mask which offers a defilade for the friendly troops, it is safe for over head fire as:

The lowest bullets that can clear the hill, however, are represented by the 850 yard trajectory. Any low lying bullets including the lower half of the 100% zone will strike the crest of the hill.

The difference in mils between the troop trajectory 500 yards and the mask trajectory 850 yards is 6 mils. And 9 mils at 900 yards, the troop distance, is 5½ yards.

Therefore it is seen that the lowest bullet that can clear the hill will pass 17 feet over the heads of the friendly troops.

In order to get the direction for the gun, use a protractor on the map at G_2 and read the direction of T from G_2 as S 30° E.

The firing data for the gun is then:

Elevation = 1180 yards or 19 mils.

Deflection = S 30° E.

The elevation is for a quadrant, clinometer or rear sight leaf on a level aiming point.

The direction is laid by compass bearing.

B. A natural aiming point on the crest of the hill, such as an angle in a stone wall may be utilized as follows:

For Elevation

The vertical angle from the gun to the aiming point is 10 mils. As the aiming point is above, subtract this vertical angular difference from the elevation of 19 mils on the gun, giving as a result 9 mils.

9 mils = 790 yards elevation.

For Deflection

The aiming point is 5 yards to the right of the line of sight.

5 yards @ 400 yards = 12½ mils.

12½ mils = 10 points windage approx.

10 points left windage is the correct deflection.

Indirect Firing Precaution

The gunner can always determine whether the trajectory will clear an intervening obstacle between his gun position and the target by first laying his gun to hit the target and then without disturbing his piece reset his sight to a range corresponding to the distance the obstacle is from the gun. His sheaf will clear only if his line of sight clears.

*See Overhead Fire. (Page No. 49).

UNIVERSAL RULE FOR DETERMINATION OF SIGHT SETTING

1. Determine trajectory necessary to hit target on horizontal plane.
2. Add algebraically the angle of site to the target, using proper sign plus or minus.
3. Subtract algebraically the angle of site to the aiming point, using proper sign plus or minus.

Summary

1. Includes all cases:
   - A. With direct fire on any target.
   - B. Indirect fire with level aiming point or a quadrant on a target on a horizontal plane with gun.

1 and 2. Includes all cases:

Of indirect fire with a level aiming point or a quadrant when the target is not on the horizontal plane of the gun.

1, 2 and 3. Includes all cases:

Where indirect fire is used on a target, using an aiming point not on the horizontal.

FIELD METHODS OF READING VERTICAL ANGLES MEASURED FROM A HORIZONTAL PLANE

Method No. 1

1. Clinometer, quadrant and pocket transit.
2. Level and gun.
3. Level gun and mil scale.
4. Level and mil field glass.
5. Slope boards.

Methods 1 and 5 need no explanation as the use of a clinometer, quadrant and slope board are more or less universal.

The other methods are improvised ones dependent upon the use of a small pocket level. When a pocket level is not available, make a plumb line with a string and bullet and fasten to the gun at some convenient place such as the handle on the Colt machine gun, letting the string hang along the rear straight edge of the side plates.

The line of the distant horizon can always be considered to be on a level with an observer's eyes and can be used as a level point as a last resource.

Method No. 2

A. To measure depression angles (angles below horizontal plane).

Level the gun with the pocket level and without moving the gun, alter the sights until the line of sight is on the mark to be measured. Note the reading of the sight and look up its value in mils from the angle of departure table.

B. To measure elevation angles (angles above horizontal plane).

Level the gun with the pocket level, set the sights at zero and determine a level point by looking along the sights and locating the point where they strike the ground. Then without moving the sight elevate the gun until the zero line of sight is on the mark. The sight is then raised and the procedure carried out as for a depression angle considering the level point first located as the lower line of the angle.

Method No. 3

This method is somewhat similar to No. 2, except that after the level point has been located, the vertical angle between the level point and the other point is read direct with the mil scale.

Method No. 4

Fasten a small level to the frame of a field glass fitted with a mil scale. Determine which graduation of the mil scale corresponds to the level point when the bubble is centered, by trials.

After this graduation has once been determined, fix it in mind. Then in order to read a vertical angle, center the bubble of the level and read the mils between the graduation corresponding to the horizontal point and the point to be measured.

Correction of Indirect Fire

The observer is the eyes of the gunner during indirect firing. A simple, efficient system of fire signals are necessary between the observer and the gun commander in order to keep the guns on the target. The gun is the only range finder after all.

Indirect fire formulas and methods are only intended to place the first burst of fire where it can be best observed. After the burst is once picked up by the observer's glasses, it must be directed and held on the target.

In order that the correction of fire by observation is facilitated, the aiming points used for indirect fire should be kept on or near the level of the gun. Then the range to the target and the sight setting on the rear sight leaf will correspond and a burst of fire short or over will be corrected by this amount on the sight leaf.

In case the aiming point is not on the horizontal, corrections to the range must be made for the true range and not for the range as indicated on the sight leaf.

Example. Range 1500 yards. Sights set for aiming point 30 mils above the target or 125 yards elevation. Upon opening fire the burst is 200 yards short. What is the correction?

In order to correct the fire 200 yards at 1500 yards or in other words throw it to 1700 yards will require, according to the table of elevations, over 9 mils increased elevation. Upon raising the sight leaf 200 yards above the sight setting of 125 yards gives 325 yards, which the table shows to be an increase of about 1¾ mils. And 1¾ mils at 1500 yards will throw the sheaf about 40 yards when it should throw it 200.

If, however, 9 mils were added to the 125 yard sight setting it would bring the new sight setting to about 825 yards, which would be the proper correction to make.

When the table of elevations is at hand or the Milometer, corrections can be made as above.

For guns having a rear sight elevating screw head one turn of which is one mil, corrections can be made by the following approximate rule.

Note in the table of elevations that the difference between ranges for each hundred yards from beyond short range up to beyond distant ranges, is about ¼ as many mils as there are hundreds of yards in the range.

Hence a "rule of thumb" for mils, which in turn can be applied to turns of the rear sight elevating screw head is: To alter the machine gun sheaf 100 yards at any range, change the elevation on the rear sight ¼ as many mils as there are hundreds of yards in the range.

Note that this rule is applicable to any machine gun which has a rear sight with an elevating screw head, one turn of which alters the sight setting an amount which can be determined in mils.

Night Firing

Night firing can readily be done with machine guns by using indirect firing methods and artificially illuminating the aiming point used.

The illuminated aiming point usually consists of a box closed towards the enemy and with the side toward the gun covered with a semi-transparent cloth. Lines drawn on the cloth are made to stand out in relief by a flash light placed in the box.

A convenient distance to place the box is 14 yards from the gun and with the aiming lines on the cloth measured in even inches.

Each half-inch on the cloth is then a mil and accurate placing of the fire is possible.

Much ingenuity must often be exercised in the placing of the night firing points. Luminous paint or "radiolite" points may often be utilized successfully. The night firing box can be placed on the flank of the gun, in the trench and reflected to the sights of the gun by a mirror placed on the parapet of a trench.

Overhead Fire

Overhead fire has already been discussed under the map indirect firing problem. (See page 46)

An additional problem of overhead fire using the safety angle of 1 degree from the lowest bullets of the sheaf to the friendly troops is given here.

Method. Troops may advance to a range where the angle of elevation of the gun for that range plus the angle of safety, including

the lower half of the 100% zone, is equal to the angle of elevation necessary to use on the gun to fire at the target. Or expressed in known terms, troops may advance to a range determined by subtracting the angle of safety plus ½ the 100% zone from the angle of elevation used on the guns for firing on the target.

If the angle of safety is considered to be 1 degree or 17¾ mils and ½ the 100% zone is considered to be 3¾ mils, the total angle to subtract will be 21 mils approximately.

Example. Range 1800 yards. If the terrain is more or less flat, how far may our troops advance before overhead fire would be rendered unsafe?

Angle of elevation 1800 yards	=45.3 mils.
Subtract	21.0 mils.

Range whose angle of elevation = 24.3 mils is 1325 yards.

The danger zone defined by the angle of safety should be increased 2½ mils for every 100 yards of additional range beyond 2000 yards. That is if the range is 2200 yards use 26 mils, as the angle of safety and for 2400 yards use 31 mils, etc. This is a necessary precaution because of the larger errors in the determination of the range and the variation in the 100% zone.

Note. Overhead fire must not be opened on level ground unless the troops are 600 yards away and the target at least 1400 yards, on account of the rising branch of the trajectory.

The angle of safety for the rising branch is considerably smaller than for the falling branch as the variation for an error in range would not be dangerous and at long ranges (2000 yards) troops 300 yards in front of the gun position may be safely fired over.

Precaution for Overhead Fire

The method above given is correct in principle for determining the practicability of utilizing overhead fire because it is based on an actual angle between the lowest bullets of the machine gun sheaf and the advancing troops.

However, the factor of safety of one degree above cited, in all cases may not be nearly great enough or may be too great, depending upon a number of other conditions which may render overhead fire so dangerous on level ground as to be prohibitive.

Such conditions are:

1. Accuracy of range.
2. Visibility of target.

*See Overhead Fire. (See page 49.)

3. Conditions for observation.
4. Type of machine gun.
5. Condition of barrel.
6. Method of mounting gun.
7. Expertness of gunner.
8. Nature of soil upon which mount rests.

Therefore, because of these variable conditions the machine gun officer, if required to fire over his own troops, must use that factor of safety, which will assure his fire reaching the target and not his own comrades.

After determining his factor of safety, the method outlined will give him the remaining data as scientifically as it can be computed.

Long Range Searching or Barrage Fire

The relation of ground to the effect of fire must be thoroughly studied in order to achieve the most effective results with long range firing from machine guns.

By selecting appropriate trajectories at long ranges, defiladed space under short range fire becomes a suitable target at the longer ranges. In this manner supply stations, lines of communication and supports of the enemy on the reverse slope of hills from our front line trenches, may be effectively brought under a curtain of fire from our second line positions.

With an accurately contoured map this is accomplished by first calculating the reverse slope angle in mils using the formula:

$$M = \frac{1000\ W}{R}$$

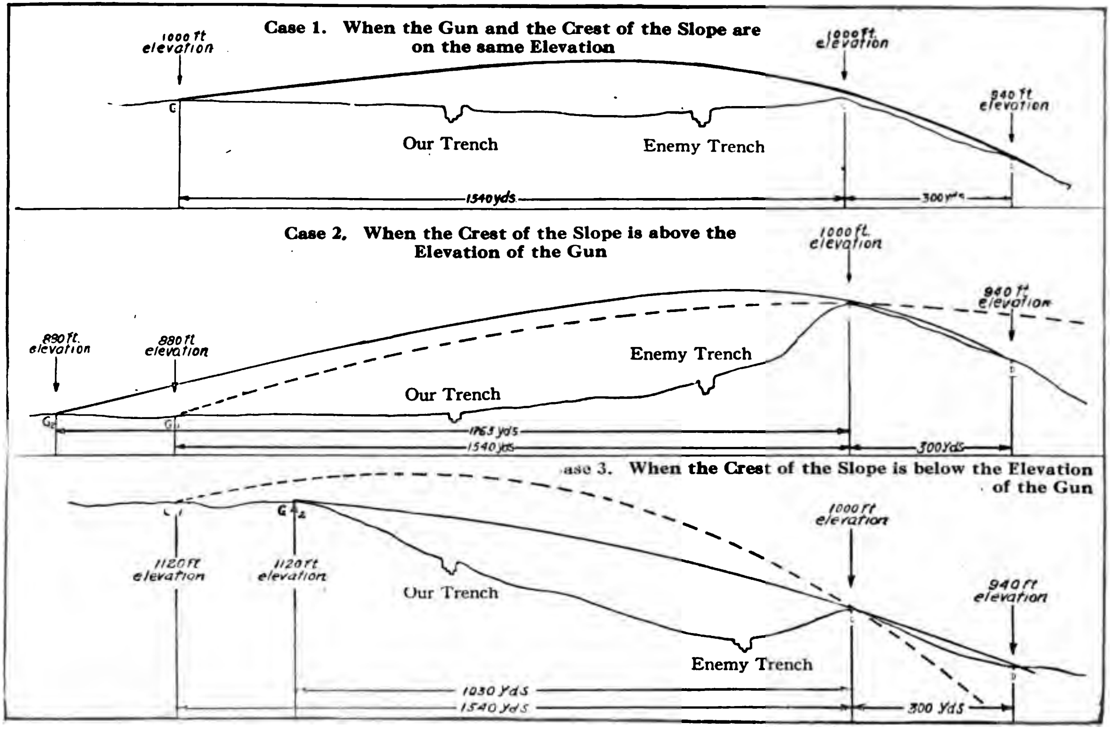
and substituting the values of W and R from the difference in elevation in feet between a point on the crest of the slope and one at the bottom and the horizontal distance between the two points.

Knowing the reverse slope angle we must select a trajectory whose angle of fall will approximate the reverse slope angle. This problem can be solved by making a profile of the map to the same scale as a transparent drawing of all the trajectories.

By superimposing the trajectory drawing over the profile, by inspection the trajectory whose angle of fall approximates the reverse slope angle can be selected.

However, the problem can be solved just as quickly with a table to a slide rule showing angles of fall, thus eliminating the bulky trajectory drawing and the making of a profile.

Fig. 29 LONG RANGE SEARCHING OR BARRAGE FIRE



The general rule or formula by which the appropriate trajectory is selected is as follows:

The trajectory at a range "R" whose angle of fall equals the reverse slope angle is the trajectory whose angle of fall is the algebraic sum of the reverse slope angle and the angle of site from "R" to the crest of the hill.

This rule may be understood more clearly by considering the three following cases regarding the location of the target with respect to the position of the gun:

GENERAL RULES

Case 1

When the gun and the crest of the slope are on the same elevation the angle of site becomes zero and range R will be the trajectory whose angle of fall EQUALS the reverse slope angle.

Case 2

When the crest of the slope is above the elevation of the gun use the trajectory at range R whose angle of fall is the SUM of the reverse slope angle and the angle of site to the crest from range R.

Case 3

When the crest of the slope is below the elevation of the gun use the trajectory at range R whose angle of fall is the DIFFERENCE between the reverse slope angle and the angle of site to the crest from range R.

In both Case 2 and 3 there is only one known quantity, the reverse slope angle, and two unknowns, the angle of site and range R. Consequently several trials will have to be made in order to meet the conditions of the formula.

The method of procedure for both Case 2 and Case 3 will be as follows:

Select the trajectory whose angle of fall equals the reverse slope angle. At a range from the crest equal to this trajectory locate R on the map and calculate the angle of site to the crest of the reverse slope by the difference in elevation between the two points and the horizontal distance between them, similarly to the reverse slope calculation.

Add this angle of site to the angle of fall of the trajectory if the crest is higher than the gun or subtract it if it is lower and look up the new trajectory whose angle of fall equals the sum or difference of the two.

For small angles of site and where the nature of the terrain in the vicinity of the gun is level, this trajectory will be the correct range and sight setting to use for the line of sight to be directed at the crest.

If, however, the angle of site is large, over 10 mils, and the gun position as just determined is on sloping ground a series of calculations must be made as follows:

Calculate the angle of site from the gun in its last determined position: i. e., the range whose trajectory has an angle of fall equal to the algebraic sum of the reverse slope angle and the angle of site for that range; and take the algebraic sum of this angle of site and angle of fall for that range and again look up a new range whose trajectory has an angle of fall that corresponds to the algebraic sum.

This cycle of operations must be carried on until there is no appreciable difference between the angles of site due to the change in range.

After the first determination of the range, taking into consideration the nature of the terrain, the fire control officer should be able to select the proper trajectory by inspection and verify it in a moment by calculating the angle of site and determining whether the algebraic sum of the angle of site and the angle of fall will equal the reverse slope angle.

The cycle of operations are best performed by tabulating the data as shown in the examples for Case 2 and Case 3.

Example Case 1.

When the crest of the reverse slope is on the same approximate elevation as the gun.

From the contours the difference in elevation between points C and D on the reverse slope is seen to be 20 yards (60 feet) in 300 yards horizontal distance.

Therefore the slope angle is:

$$M = \frac{1000\ W}{R} = \frac{1000 \times 20}{300} = 67 \text{ mils.}$$

From a table or the Milometer giving angles of fall the trajectory whose angle of fall corresponds to 67 mils is seen to be 1540 yards.

Hence the firing data for searching the reverse slope with fire is:

Range = 1540 yards from the crest.
Sight setting = 1540 yards.
Aiming point = the crest.

Example Case 2.

When the position of the reverse slope is at an elevation above the position of the gun.

As in Case 1 the trajectory whose angle of fall equals the reverse slope angle is 1540 yards. The crest of the hill is seen to be 40 yards above the elevation of the gun and the gun must be elevated this angle in order to clear the crest. If, however, it is elevated this much the angle of fall will also be changed a corresponding angle and will no longer equal the slope angle but will be less. In order to make the angle of fall parallel the slope again, the angle the gun was elevated must be added to the angle of fall.

The angle the gun was elevated is the angle of site to the crest: Or

$$M = \frac{1000\ W}{R} = \frac{1000 \times 40}{1540} = 26 \text{ mils.}$$

The slope angle = 67 mils.
Angle of site = 26 mils.
Total = 93 mils.

The trajectory whose angle of fall equals 93 mils is found to be 1790 yards. However, upon moving back to 1790 yards on account of the increased distance to the crest, the angle of site is changed. The angle of site for 1790 yards is:

$$M = \frac{1000 \times 40}{1790} = 22.4 \text{ mils.}$$

And the new trajectory would be:

Slope angle = 67 mils.
Angle of site = 22.4 mils.
Total = 89.4 mils.

The trajectory whose angle of fall equals 89.4 mils is 1760 yards. The entire cycle of operations should be tabulated as follows:

TABULATION

Reverse Slope Angle	Angle of Site	Angle of Fall (Algebraic Sum of Col. 1 and 2)	Trajectory
67	0	67	1540
67	26	93	1790
67	22.4	89.4	1760
67	22.7	89.7	1765

Note that column 1 is always known and never varies during the cycle, column 2 is obtained from the preceding row in column 4, column 3 is the algebraic sum of column 1 and column 2, and column 4 is always obtained from column 3.

With an ordinary slide rule and a table of angles of fall, or with the Milometer alone, the entire cycle is calculated quite rapidly. By inspection it should be solved in three operations at the most.

In this problem then, the last trajectory in column 4 or 1765 yards would be the sight setting for aim taken at the crest at a range from the crest of 1765 yards.

This range is scaled on the map and the gun position located accordingly.

Regardless of the nature of the terrain the appropriate trajectory can always be selected as above.

Example Case 3.

When the crest of the reverse slope is at an elevation lower than the position of the gun.

As before the trajectory whose angle of fall equals the slope angle is 1540 yards.

The crest of the hill is seen to be 40 yards below the elevation of the gun and the gun must be depressed this angle in order to clear the crest. If, however, it is depressed this much the angle of fall will also be changed a corresponding amount relative to the slope and will no longer equal the slope angle but will be greater.

In order to make the angle of fall parallel the slope again the angle the gun was depressed must be subtracted from the angle of fall.

The angle the gun was depressed is the angle of site to the crest or 26 mils.

Slope angle = 67 mils.
Angle of site = 26 mils.
Total = 41 mils.

The trajectory whose angle of fall equals 41 mils is found to be 1225 yards.

Tabulating as in Case 2.

TABULATION

Reverse Slope Angle	Angle of Site	Angle of Fall (Algebraic Sum of Col. 1 and 2)	Trajectory
67	0	67	1540
67	26	41	1225
67	32.6	34.4	1130
67	35.4	31.6	1080
67	37	30	1055
67	37.9	29.1	1040
67	38.4	28.6	1035

Hence firing data for searching the reverse slope with fire is

Range = 1035 yards from the crest.
Sight setting = 1035 yards.
Aiming point is the crest.

PART III

THE MILOMETER OR BALLISTIC SLIDE RULE AND MIL CALCULATOR

Five essential parts.

1. The inches scale.
2. The mil slide rule B-C.
3. The angle of site-trajectory slide D-E.
4. The mil angle of departure and of fall scales F-G-H.
5. The combination millimeter-protractor slope-board scale with formulas, on back of rule.

General Description

A computing slide rule is always more or less mysterious to those unfamiliar with its use and they are prone to think its operation is far more difficult than it really is.

The Milometer is as simple and as easily operated as any arithmetical calculation can possibly be. It requires but little more mental effort than is necessary to measure off 1 foot and 5½ inches using a yard stick.

If the instructions are carefully read and the examples studied, the principles upon which all the scales operate will be understood quickly. After that any number of problems can be solved without reference to the instructions.

Scales B and C work by multiplication and division as they are logarithmic numbers plotted to scale. They differ from scales C-D on the manheim slide rule in that one scale is the reciprocal of the other. Scales B and C of the Milometer also consist of one complete logarithmic scale from 1 to 10 and portions of two other scales of varying values.

Scales D-E operate by simple addition and subtraction, the trajectory being plotted on scale E while scale D is so arranged that angular values in mils, plotted to the same proportion as the trajectory on E, can be added or subtracted. Scale E is plotted to the increasing angle of elevation or departure of the trajectory for ranges from 0 to 3000 yards.

To use the Milometer, operate the slide C-D with the thumb of the right hand by pressing on the lower end of the slide, being careful to apply the pressure on the end of the slide only and not on the bottom or on the ends of B-E.

The Milometer is held in the left hand, face (B-C-D-E) up.

The Milometer is operated and is read similar to any slide rule. The value of the small divisions of the scales, until one is familiar with the rule, can always be determined by referring to the figures above and below and dividing the difference of any two figures by the number of graduations between them.

For instance on scale B, there are ten graduations between 300 and 400. Each graduation is then equal to 10. However, between 400 and 500 of the same scale there are only 5 graduations. Therefore each one has a value of 20.

As on any slide rule the figures on scales B-C represent units of 1, 10, 100, 1000 or whatever number is desired, it being merely a question of moving the decimal point.

However, as the Milometer is primarily for the use of range calculations it is most convenient to make the figures represent the actual ranges and for all calculations of ranges from 50 yards to 3000 and widths in yards or angles in mils from 5 to 300; it is unnecessary to use decimals as the reading is direct.

When, however, scales B-C are used for calculations other than yards and mils the decimal point must be kept in mind. And if on scale B 400 is read as 4 and 500 read as 5 then each small division between 400 and 500 will have a value of $\frac{2}{10}$.

A detailed discussion of each scale with minute instructions regarding its use will be found on succeeding pages.

The formulas on the back of the rule are self-explanatory for those familiar with windage and elevation rules, the mil system and indirect firing. They do not, however, form a text book and are merely for ready reference for one previously acquainted with their use.

They are, in some cases, "rule of thumb" rules and are only approximately true. The rear sight referred to is the one now in common use on our machine guns, such as the Colt and Vickers, and are equipped with an elevating screw head; one complete turn of which is 1 mil.

The points of windage are the standard windage graduations for U. S. rifles and U. S. ammunition.

EXPLANATION OF FORMULAS ON THE BACK OF THE MILOMETER

Range Rules

Windage

Let P=Pts. windage. V=wind velocity in miles per hour and R=range in hundreds of yards.

Rules

One point of windage moves the point of strike 4 inches for each 100 yards of range, or:
1 P=4 R inches; or at 1000 yards 1 P=4×10=40 inches.

The points of windage necessary to take for all side winds is equal to the range in hundreds of yards multiplied by the velocity of the wind in miles per hour and divided by 40; or:

$$P=\frac{RV}{40}$$

For winds from 1-5-7 of 11 o'clock take ½ P.

Telescopic Sight Windage

One point of windage on the telescope sight moves the bullet ¼ as much as one point on the Springfield Rifle or one inch per hundred yards of range.

Combat Rule for Approximate Windage

For all winds, except head and rear winds, take one-quarter as many points of windage as there are hundreds of yards in the range; or:

$$P=\frac{R}{4}$$

Note that the wind gauge is always moved into the wind. The point of strike of the bullet is moved in the same lateral direction as the base of the wind gauge is moved.

The deflection in mils, to counteract a wind is, from the windage formula

$$P=\frac{RV}{40}, \text{ found to be}$$

$$M=\frac{RV}{35}.$$

Example. Range 800 yards. Wind velocity estimated at 10 miles per hour. How many mils between the point of aim and the target?

$$M=\frac{8\times10}{35}=2 \text{ mils.}$$

Enfield Rifle Windage

On the Enfield Rifle which is without a wind gauge the deflection must be figured in mils and the gun aimed off accordingly.

Elevation

E=100 yards difference of elevation.

One hundred yards difference of elevation on the rear sight will throw the point of strike of the bullet a distance in inches corresponding to the square of the Range in hundreds of yards; or: E=R squared inches on rear sight.

Example. Range 900 yards. The sight is shifted from 900 to 1000 yards. How far has the point of strike of the bullet been changed vertically?

Substitute $E=9\times9=81$ inches.

Conversely; from the discussion of sights and the mil system if
C = change on rear sight to shift sheaf of fire 100 yards.
T = complete turns of elevating screw head.
C = ¼ as many complete turns of the rear sight elevating screw head as there are hundreds of yards in the range (see page 48 on "Correction of Indirect Fire") or
C = ¼ T Hds. yards in R.

Example. Range = 900 yards. It is desired to increase the range to 1000 yards.
Substitute

$$C = \frac{9}{4} = 2\tfrac{1}{4} \text{ mils or turns.}$$

The distance to the maximum ordinate i. e. the point where the trajectory reaches the summit is .57 of the range or
$D_M = .57\ R$.

The angle of fall is approximately twice the angle of departure, or
$A_F = 2\ A_D$.

The mil scale formulas are all discussed under Part I and the Indirect Fire Formulas under Part II

Uses of Inches, Millimeter and Mil Scales

The scale on the upper edge of the under side of the slide is a six inch scale graduated in inches and tenths inches. The scale is conveniently used by drawing the slide to the left and using the straight edge of the main body of the rule as a right angle or T-square to measure from.

On the lower edge of the slide is a six inch scale so graduated in inches and sixteenths inches that when the slide is drawn out to the right until the index represented by the arrow is just visible, the graduations on the slide then have the correct relation for a 12 inch scale as the main part of the rule and the slide are then 1 foot in length.

If a measure of less than six inches is desired, draw the slide to the left, otherwise draw it to the right.

The millimeter scale on the protractor performs two roles. It is both an angle measuring instrument and at the same time it is so graduated as to be used for linear measure.

The millimeter scale is graduated in millimeters and centimeters. Each millimeter subtends an angle of 2 mils as seen from a point $19\frac{7}{10}$ inches (½ meter) distant.

To use the mil scale fasten a non-shrinking string to the rule with a knot tied in the string at $19\frac{7}{10}$ inches,. Hold this knot to the eye with the right hand, or hold it in the teeth, while at the same time the scale is held with the left hand parallel to and nearly coinciding with the line adjoining the two objects which define the angle. By holding the zero of the scale under one object, the reading of the scale at the other object will be the angle in mils.

The Use of the Mil Scale Rule Scales B-C

The mil slide rule consists of two scales B, C. B is called range in yards, and C is called mils and width (yards) scale.

The range scale B is graduated in yards, and has an index consisting of the letter W at the 1000 yard graduation. This W signifies width which is read in yards opposite the index.

The mil and width scale C is graduated in mils, which in addition to always reading the width in mils opposite all range graduations, also indicates the width in yards opposite the 1000 yard index. Width in yards is always opposite this index and never opposite any other graduation.

The use of the mil slide rule is as follows:

R = Range in yards. W = Width in yards. M = angle, subtended by W.

Example I. Given R and M. Find W.

Set the angle in mils on scale C opposite the range in yards on scale B. Then on scale C read W in yards opposite the 1000 yard index.

Let R = 1200. M = 10. W = ?

Set 10 on scale C opposite 1200 on scale B and read 12 yards on scale C opposite 1000 on scale B.

Example II. Given R and W. Find M.

Set W (yards) on scale C opposite the index on scale B and read the angle in mils on scale C opposite the range on scale B. For instance: On a contoured map the elevation of the gun is 950′ while the target is 800′. The range scales 1100 yards. What is the angle of site (angle between target, gun and horizontal)? R = 1100. W = H = 950—800 = 150′ = 50 yards. = M = ?

Set 50 on scale C opposite the index on scale B, while opposite 1100 on scale B is found 46 mils on scale C ∴ angle of site is — 46 mils, as target is lower than gun.

Example III. Given M and W. Find R.

Set the width in yards on scale C opposite the index, and read on scale B the range opposite the mil angles on scale C.

The distance between telephone poles on a road is known to be 50 yards. The angle subtended by two of them, parallel to the front, is 60 mils. Find range. $M=60$. $W=50$. $R=?$

Set 50, scale C, opposite the index, and read 833 yards on scale B opposite 60 on scale C.

Example IV. Given D, M_1 and M_2. Find R where D = distance in yards toward or from a width, W; which subtends M_1 at initial point of D and M_2 at the other end.

Set D on scale B opposite M_2 on scale C, and read range R on scale B opposite the difference between M_1 and M_2 on scale C. Note that M_2 is always the second reading, regardless of which way D is measured.

Points on the flank of enemy trench parallel to the front are seen to subtend an angle of 200 mils. Upon pacing, measuring or estimating a distance of 200 yards to the rear, the same points are seen to subtend 150 mils.

What is the range?

$D=200$. $M_1=200$. $M_2=150$. $R=?$

Set 200 on scale B opposite 150 on scale C, and read 600 on scale B opposite 50 scale C.

Where D is measured toward the object using the above figures, M_1 would equal 150 and M_2 200. Solve as before.

Example V. Use with a contoured map.

From a contoured map, the angle of site, mask angle and troop angle are calculated on the mil slide rule as follows:

Range scales on map, 2000. Contours show target as 1000′, gun as 950′. Therefore target is 50′ higher than the gun. Find angle of site.

Use slide rule as in Example II, considering 50′ (17 yards) as W.

$$\frac{\text{Opposite index on range scale}}{\text{Set 17 yards on mil scale}} = \frac{\text{Opp. 2000 on range scale}}{\text{Read angle of site} +8\frac{1}{2}\text{ mils}}$$

Map gives mask distance as 1200 yards, and elevation above gun as 75′ (25 yards). Find mask angle. Solve as for angle of site.

$$\frac{\text{W on scale B}}{\text{25 on scale C}} = \frac{\text{1200 on scale B}}{\text{M } (+21) \text{ scale C}}$$

Similarly troop dist. = 1000 yards at 40′ above gun. Troop angle is therefore

$$\frac{\text{W on scale B}}{\text{13 on scale C}} = \frac{\text{1100 on scale B}}{\text{M (+12 mils) scale C}}$$

Precaution for Using Mil Slide Rule

Whenever W or M is of less value than 5 mils (smallest reading on scale C), assume M or W as multiplied by 10, and then take $\frac{1}{10}$ of the result as the answer.

Example. R = 1200. W = 5. Find M.

If 5, scale C, is set opposite index on scale B, 12 on scale B is above end of slide on scale C. Therefore set 50 (10×5) on scale C opposite index on scale B, and read 42 on scale C opposite 1200 on scale B. Dividing 42 by 10 gives result of 4.2 mils as M.

When the slide is below the index W use the 100 yard graduation as the index and point off one place.

Example. Range = 600.
M = 8.
Find W.

If 8 on scale C is set opposite 600 on B, the end of the slide fails to reach the index W. In this case read opposite the 100 mark on B or 48 and point off one place or 4.8 yards.

By setting 80 instead of 8 opposite 600, the upper index could have been used and the result divided by 10.

THE USE OF THE SCALES F-G-H

Example VI. Given the range, what is the angle of departure or of fall in mils for a horizontal plane.

Push sliding scale C-D up until scale F-G-H under the slider, is sufficiently uncovered. Scale G gives the range in hundreds of yards. Scales F and H in units of ten mils, each small graduation being 2 mils on F and 1 mil on H. Opposite the range in hundreds of yards on scale G read the angle of departure on scale H. Opposite the range in hundreds of yards on scale G read the angle of fall on scale F.

Example. Range 1700 yards. What is angle of departure and of fall?

The angle of departure on scale H opposite 17 on scale G is 40 mils (4×10). The angle of fall on scale F opposite 17 on scale G is 82.5 mils (8×10+2½).

Note. The angle of fall for distances beyond 1000 yards and up to 3000 is approximately twice the angle of departure.

The angle of departure may also be read on scales D-E by first setting the zero of scale D opposite the zero of scale E.

The angle of site-trajectory slide consists of two scales, the angle of site scale D and the sight leaf graduation (trajectory) scale E. The angle of site scale is graduated in mils from a center point marked zero. From zero up the angle is minus (negative), and from zero down it is plus (positive). This must not be confused with the fact that a minus angle of site is below the horizontal, etc. See definition.

The lines above and below zero, marked 100% zone, defines the limits of the 100% zone, that is the upper and lower edges of the zone where the bullets are passing in the air and hitting on the ground or theoretical horizontal surface through the gun.

The line marked "not safe" defines the danger zone of one degree, which is considered to be the factor of safety necessary for firing over troops. That is the lowest bullets of the machine gun sheaf at any range are passing over the range indicated by this line, at an angle of 1° between lowest bullets, gun and the indicated range.

Example VII. Given the range and angle of site. To find the quadrant angle of elevation (sight setting) when the gun is level. Set the angle of site, plus or minus, depending upon whether the target is above or below the level of the gun, on scale D opposite the range on scale E, and read the quadrant elevation in yards on scale E opposite the zero on scale D.

Let R = 1200 yards. Angle of site +30 mils.

Quadrant elevation is found by setting + 30 of scale D opposite 1200 of scale E, and reading 1890 on scale E opposite the zero on scale D.

Example VIII. Given the range, angle of site, mask distance and mask angle. Find whether the mask will be cleared by the trajectory when the gun is firing on the target.

1. Find the sight setting necessary to hit the target from the range and angle of site as in Example VII.

2. Determine the sight setting necessary to hit the crest of the mask, knowing the distance to crest of mask, and the angle to crest of mask. Solve as in 1.

3. Set the zero of scale D opposite the sight setting on E, necessary to hit the target (determined in 1).

Then the relation of the graduation on scale E, showing the sight setting necessary to hit the crest of the mask, to the lowest line "100% zone" on scale D, indicates whether the mask will be cleared.

The sight setting on scale D necessary to hit the mask, shows the position on the top of the mask in relation to the sheaf required to hit the target, the lower limits of this sheaf being shown by the 100% zone line.

Thus, if the 100% zone line is above the sight setting necessary to hit the mask, then the entire sheaf will clear the mask. If, however, the same sight setting required to hit the target also hit the crest of the mask, then it is evident that only the upper half of the 100% zone would clear the mask.

Given R = 2000 yards. Angle of site +20 mils; mask distance 1400 yards, mask angle +45 mils. Find the clearance.

1. Sight setting necessary to hit the target, following the method of Example VII, is found to be 2300 yards.

2. The sight setting necessary to hit the mask is found in a similar way to be 2240 yards.

3. Set the zero of scale D opposite 2300 (sight setting for target) on scale E, and note that the 100% zone line is about 2250 on scale E, and is therefore just above 2240 the mask sight setting, hence the mask will be cleared by the lowest shots of the 100% zone by a narrow margin.

The value of the 75% zone and the 100% zone as shown on the scale must be modified somewhat for short and long ranges.

For beaten zones under 1000 yards range decrease the value of the 75% zone by one mil and the 100% zone by two mils.

For beaten zones over 2000 yards range increase the value of the 75% zone by one mil and the 100% zone by two mils for each 1000 yards of range beyond 2000 yards.

In other words up to 1000 yards the 75% zone is about 3 mils and the 100% zone about 5½ mils. For 2200 yards the 75% zone is 6 mils and the 100% zone 11½ mils for 2400 yards they would be 8 mils and 15½ mils respectively, etc.

Example IX. Given the range, angle of site, troop distance and troop angle. Find whether it will be safe to fire over the troops.

Proceed as in VIII, substituting the "not safe" line for the "100% zone" line.

Similarly, if the "not safe" line is above the sight setting necessary to hit the troops, overhead fire is safe.

However, if the line on scale E indicating the sight setting necessary to hit the troops, is between the "not safe" line and the zero on scale D, then overhead fire is not safe, as the factor of safety of one degree is not secured, and the troops are within the danger zone.

R = 1500 yards. Angle of site +20 mils. Troop distance 1100 yards. Troop angle +10 mils. Is overhead fire safe?

1. Target sight setting is 1900 yards.
2. Troop sight setting is 1400 yards.
3. When the zero of scale D is opposite 1900 on scale E, the "not safe" line is above 1400, hence overhead fire is safe, as the heads of the troops are cleared by over one degree.

The safety zone defined by the "not safe" line should be increased 2½ mils for every 100 yards of additional range beyond 2000 yards. That is if the range is 2200 yards use 26 mils as the "not safe" line and for 2400 yards use 31 mils, etc. This is a necessary precaution because of the larger errors in the determination of the range and the variation in the 100% zone.

Example X. Given range. Find depth on the ground surface of the 100% beaten zone (i. e. intersection of the ground with the machine gun sheaf).

Set zero of scale D opposite the range on scale E. Then read the ranges on scale E opposite the 100% zone lines on scale D.

Example. Range 1500 yards. Set zero D at 1500 B and read lower limit of 100% zone as 1410 yards and upper limit as 1580 yards. Therefore the beaten zone extends from 1410 to 1580 yards for the 1500 yard trajectory.

The above discussion of the 100% zone is for a level gun on a horizontal plane surface.

Where the ground is sloping, it will be necessary to use Von Rohnes formula. (See S. A. F. M.)

$$B = \frac{a\,b}{a+s} \text{ in which}$$

B = Depth of beaten zone on sloping ground.
a = Angle of fall in degrees.
b = Depth of beaten zone on level ground.
s = Slope of sloping surface in degrees.
s = Plus on rising slope.
s = Minus on falling slope.

The following examples require the use of both the mil slide rule and the trajectory slide rule.

Example XI. Given the range and abscissa (distance horizontally in yards to ordinate). Find height of ordinate (vertical distance from ground to trajectory at abscissa) in mils and in yards.

Set the zero of scale D opposite the range graduation on scale E, which corresponds to the abscissa. Then read the height of the ordinate in mils on scale D opposite the range graduation on scale E.

Knowing this angle in mils, convert to yards by using the abscissa as range, the ordinate as M and finding W by use of the mil slide rule scales B, C.

Range 1300 yards. What is ordinate at 800 yards?

$$\frac{\text{Zero scale D}}{\text{800 scale E}} = \frac{\text{1300 scale E}}{\text{Read 14 mils scale D}}$$

To convert to yards:

$$\frac{\text{14 scale C}}{\text{800 scale B}} = \frac{\text{Index scale B}}{\text{Read 11 plus yards scale C}}$$

Note. The distance to the maximum ordinate is approximately .57 times the range in yards.

Example XII. Given range and difference in elevation in yards between the gun and target. Find proper setting of sight for horizontal aiming point.

1. Convert yards to mils by mil slide rule. (Same as determining angle of site.)

2. Add or subtract, depending whether target is above or below gun, the angle of site in mils, using trajectory slide.

Range = 1200. Target 30′ above gun. Find sight setting

1.

$$\frac{\text{10 scale C}}{\text{1200 scale B}} = \frac{\text{Index scale B}}{\text{Read 12 scale C}}$$

2.

$$\frac{+\text{ 12 scale D}}{\text{1200 scale E}} = \frac{\text{Zero scale D}}{\text{Read 1525 scale E}}$$

Other uses of the machine gun slide rule are as follows:

Example XIII. Given range. Find combined sight setting or searching fire in mils. Determine mentally the probable error in the range.

Range Errors.

Fixed base range finders..........	5%
Scaled from map..................	10%
Estimation.......................	15%

The effective beaten zone or 75% zone must include the target within its limits. The effective beaten zone can be considered to extend two mils on each side of the zero mark which will give the total depth of the zone of 4 mils. Four mils at 1200 yards equals an effective beaten zone of about 120 yards. At 2000 yards it would be about 70 yards.

Combined sights or the amount of searching fire depends upon the depth of the beaten zone and the probable error in the determination of the range. These factors are somewhat variable.

However, if the probable error in the range does not exceed ½ the effective zone then combined sights or searching fire is unnecessary.

When the probable error exceeds one-half the effective zone combined sights should be used. One sight should be set above the range and the other below it, the difference between the two sight settings equaling the depth of the zone for that range.

If the probable error is two or more times as large as the effective zone, three settings of the sight would be necessary. One sight would be set for the range, one above and one below, the difference between the sight settings being equal to the depth of the zone.

With the Milometer the sight setting for combined sights and the amount of searching is determined as follows:

Set the zero of scale D opposite the range on scale E. If the 2 mil graduation above and below the zero are above and below the probable error in the range, combined sights or searching fire are unnecessary.

If the 2 mil graduations are included between the limits of the probable error in the range proceed as described above.

Example. Range determined by scaling from a map is found to be 1200 yards. Probable error is 10%, so that range may be 120 yards less or greater or 1080 yards as the least range and 1320 as the longest range.

Should combined sights be used? If so, what are the sight settings?

Set zero of scale D at 1200 on scale E and read on scale E the ranges opposite the 2 mil graduation above and below the zero on scale D which are 1260 and 1140 yards. As 1260 and 1140 yards

represents the respective upper and lower edge of the effective zone and 1320 and 1080 yards as the possible ranges, it is evident that the target may not be included in the beaten zone.

The reading of the mil graduations on scale D opposite the 1320 and 1080 yard graduations on scale E equals nearly eight mils or twice the amount represented by the beaten zone. Two sight settings will just include the target.

The *upper* sight setting will be the range on scale E opposite the 2 mil graduation *above* the zero on scale D or 1260. The *lower* sight setting will be the range on scale E opposite the 2 mil graduation *below* the zero on scale D or 1140.

Similarly the amount of searching fire would be 2 mils above target and 2 mils below, as the amount of searching fire in mils would be the number of mils in the beaten zone corresponding to the number of sight settings used for combined sights. If two sight settings are used searching fire would be the number of mils necessary then the searching would be 8 mils, etc.

By utilizing searching fire with the amount of searching equal to the total number of mils between the estimated range and the lowest and highest ranges determined from the probable error, in this case 8 mils, the target may be located momentarily in the exact center of the beaten zone. This, however, is impractical as the amount of searching is too great.

The actual amount of searching fire required to bring the target within the outer limits of the 75% zone will be the total number of mils between the highest and lowest ranges determined from the probable error, less the depth of the 75% zone in mils.

This is determined by setting the zero of scale D at the lowest range on scale E and reading the number of mils on D opposite the longest range on E. From this result subtract the 75% zone of 4 mils.

In this problem the amount of searching is found to be:

No. of mils between shortest and longest range	8
Depth of 75% zone	4
Difference or amount of searching	4 mils.

This result happens to coincide with the result found by taking the number of mils in the beaten zone corresponding to the combined sight setting because two sight settings differing from each other by the depth of the beaten zone exactly equaled the probable errors in range.

If the probable error in range had been two mils less in depth it would have still required two sight settings for combined sights while requiring two mils less searching. It is evident then that as a general rule when searching is used and the amount determined by the above rule it is far more effective than combined sights as it covers the exact amount of ground necessary and covers it more evenly.

Example XIV. Given range. What is the sight setting for an auxiliary aiming point?

Measure the angular distance in mils between the target and the aiming point. When the target is above the aiming point, add this angular distance to the sight setting for the range, and when it is below, subtract it.

Range 1200. Aiming point 25 mils below the target.

$$\frac{\text{Plus 25 scale D}}{\text{1200 scale E}} = \frac{\text{Zero scale D}}{\text{Read 1800 scale E}}$$

Hence a sight setting of 1800 yards is required.

Example XV. Given range and impact of burst of fire not on the target. Adjust the impact on target.

1. For elevation, measure the vertical angular distance between the target and the center of impact (estimated) in mils. Estimate the number of yards horizontally between the target and center of impact. If the impact is below the target add the mil reading to the range. If above, subtract. After adding the mil reading, if the impact is short, add, if over, subtract the estimated shortage or excess in yards to range found by the sum of angular mil distance and original range.

2. For deflection.

Measure the horizontal angular distance between the target and impact. Take as many points of windage in the opposite direction as may be necessary, considering 1 point of windage as 1⅓ mils.

Range 1000 yards. Impact 5 mils low, 100 yards short and 12 mils to the right of the target. What is the true elevation and windage?

1.

$$\frac{\text{Plus 5 scale D}}{\text{1000 scale E}} = \frac{\text{Zero scale D}}{\text{Read 1175 scale E}}$$

$1175+100=1275$ yards correct elevation.

2. 12 mils right $\dfrac{12}{1\frac{1}{6}} = 10$ mils windage left for correct windage.

Note. When using an auxiliary aiming point, make corrections on the true range and not on the sight setting of the sight for the auxiliary point.

Example XVI. From a contoured map the horizontal difference in yards and the difference in elevation in feet between two points on a slope is scaled. What is the slope angle in mils?

Change feet to yards and solve as in Example II, calling difference of elevation W.

Note. This method of calculating slopes is also true of the metric system.

Example XVII. Given the slope angle in mils (according to preceding example) of a reverse slope, what trajectory must be used to search the reverse slope with long range searching or barrage fire?

Determine angle of fall from scale F that corresponds to slope angle.

Note that range in yards opposite the angle of fall will be the correct trajectory to use in order to have the angle of fall approximately parallel to the slope of the ground. This would be for the crest of the slope as an aiming point on a horizontal plane with the gun at the same range as the trajectory.

If the crest or aiming point is not on the horizontal plane of the gun, proceed as indicated in Part II.

Example XVIII. Given data in meters, mils, centimeters, kilograms and kilometers. To convert to yards, minutes, inches, pounds and kilometers.

On scale C are the following indexes which are listed with their names and their proportion in the table below.

y (yards) : m (meters) = 82 : 75.
min. (minutes) : mils = 55 : 16.
in. (inches) : cm (centimeters) = 26 : 66.
lb. (pounds) : kg (kilograms) = 75 : 34.
mi. (miles) : km (kilometers) = 87 : 140.

Therefore to convert yards to meters set index y of scale C on yards of scale B and read meters on scale B opposite index in. on scale C.

The other indexes are used similarly. In order to keep the decimal point correct note that since meters are larger than yards the reading will be slightly less.

Note that the mils will be about $\frac{1}{3}$ of the minutes, centimeters about 3 times the inches, kilograms about $\frac{1}{2}$ the pounds and kilometers about twice the mils.

The conversion on the slide rule is simple and direct and should not be confused as the proportion is automatically carried out..

For instance to convert minutes to mils set index "min" opposite the 1000 mark on scale B. Then the mil index reads 291 on scale B. If 1 minute is converted to mils it will be 291 mils, remembering that the mil reading will be about $\frac{1}{3}$ of the minute. If 10 minutes are converted it would be 2.91 mils, etc.

Example XIX. Use of protractor on back of rule as a slope board for determining vertical angles approximately.

Tie a bullet or other weight to mil string to act as plumb-bob and line. Let the plumb line extend over face of protractor, holding rule vertical and use the upper edge of rule as a sighting line.

TABLE I

INDIRECT FIRE SIGNALS FOR OBSERVATION OF FIRE

P (Plus) = Fire observed 50 yards beyond target.
PP = Fire observed 100 yards beyond target.
M (Minus) = Fire observed 50 yards short of target.
MM = Fire observed 100 yards short of target.
R (Right) = Fire observed to right of target.
L (Left) = Fire observed to left of target.
D = Direction is correct.
RR (Right range) = Range is correct.
Q (Question) = Observed but uncertain.
U = Unobserved.
OA = Out of action.

FORMULAS FOR ANGLE OF SITE, USING INDIRECT FIRE FROM MAP

Let A = (angle of site) angle between target, gun and horizontal plane, which is necessary to add to the angle of departure.

D = Diff. in elevation between target and gun (taken from contours).

R = Range in yards.

Example. D = 10 ft., $3\frac{1}{3}$ yds., 120 in. R = 1000 yds

(1) Angle of site in minutes (D = feet)

$$A = \frac{1146\ D}{R} = \frac{1146 \times 10}{1000} = 11.5 \text{ min.}$$

When D = inches.

$$A = \frac{D}{\text{Hds. yds. in range}} = \frac{120}{10} = 12 \text{ min.}$$

(2) Angle of site in degrees (D = ft.).

$$A = \frac{20\ D}{R} = \frac{20 \times 10}{1000} = .2 \text{ degrees.}$$

(3) Angle of site in mils (D = yds.).

$$A = \frac{1000\ D}{R} = \frac{1000 \times 3\frac{1}{8}}{1000} = 3\tfrac{1}{8} \text{ mils.}$$

(4)

$$A = \frac{20\ D\ (\text{ft.})}{R} \text{ in degrees.}$$

(5)

$$A = \frac{1000\ D}{R} \text{ in mils.}$$

TABLE II

FORMULAS CONSOLIDATED

Mil Scale

R = range (yds.) W = width (yds.) M = mils (subtended by W).

$$R = \frac{1000\ W}{M} \quad W = \frac{R\ M}{1000} \quad M = \frac{1000\ W}{R}$$

D = base. M_1 = 1st mil read. M_2 = 2nd mil read.

$$R = \frac{D\ M_2}{\text{Diff. between } M_1 \text{ and } M_2}$$

RANGE RULES

P = Pts. windage. V = wind velocity mils per hr. R = range (Hds. yds.).

1 P = 4 R inches. $P = \frac{RV}{40}$ $P = \frac{R}{4}$

M = mils deflection. $M = \frac{RV}{35}$

E = 100 yds. diff. elevation. E = R squared inches.

INDIRECT FIRE FORMULAS.

A = angle of site. G = gun. T = target. O = observer. AOT = target angle at O.

AOG = gun angle at O.

(1.) $A = \dfrac{OT \times A_{OT} - OG \times A_{OG}}{GT}$ in degrees, minutes or mils.

R = range in yards. D = difference in elevation between target and gun in feet.

(2.) $A = \dfrac{1146\ D}{R}$ in min. when D = inches.

(3.) $A = \dfrac{\text{Hds. yds. in } R}{D}$ in minutes.

(4.) $A = \dfrac{20\ D\ (\text{ft.})}{R}$ in degrees.

(5.) $A = \dfrac{1000\ D}{R}$ in mils.

Distance to maximum ordinate = DM.

DM = .57R.

AD = angle of departure. AF = angle of fall.

AF = 2AD.

C = change on rear sight to shift sheaf of fire 100 yards.

T = complete turns of rear sight elevating screw head.

C = ¼ T × Hds. yds. in R.

MAP READING

Map Visivility.

A and B = 2 points on contoured map. P = point between A and B.

DX = difference of elevation of A and B. DY = difference in elevation of A and P.

M = distance AB. N = distance AP.

$\dfrac{N}{D_Y}$ equals or less $\dfrac{M}{D_X}$ then B is visible from A.

Scale for 2000 Paces.

S = total length of scale desired in inches.

R.F = maps representative fraction expressed as a fraction.

Y = number of paces in 100 yards.

$S = R.F \times \dfrac{7{,}200{,}000}{Y}$

TABLE III

FIRE TABLE U. S. RIFLE. Cal. 30

Range Yards	Angle of Departure		Angle of Fall	
	Minutes	Mils	Minutes	Mils
100	2.424	.705	2.576	.750
200	5.152	1.499	5.827	1.68
300	8.275	2.4095	9.978	2.90
400	11.831	3.445	15.240	4.44
500	15.918	4.632	21.937	6.39
600	20.650	6.009	30.435	8.85
700	26.104	7.598	41.137	11.97
800	32.441	9.443	54.543	15.88
900	39.785	11.581	70.814	20.61
1000	48.198	14.027	89.669	26.14
1100	57.728	16.802	110.917	32.30
1200	68.379	19.90	134.310	39.10
1300	80.131	23.33	159.762	46.50
1400	92.987	27.07	187.418	54.56
1500	106.951	31.13	217.390	63.37
1600	122.038	35.53	249.745	72.72
1700	138.272	40.23	284.621	82.81
1800	155.674	45.32	322.245	93.85
1900	174.277	50.74	362.746	105.52
2000	194.111	56.48	406.364	118.30
2100	215.247	62.67	453.479	132.00
2200	237.744	69.196	504.208	146.66
2300	261.664	76.14	558.963	162.73
2400	287.091	83.55	618.230	179.86
2500	314.127	91.44	681.568	198.36
2600	342.850	99.85	750.050	218.31
2700	373.303	108.62	823.750	239.82
2800	405.854	118.15	902.970	262.88
2900	440.404	128.17	989.021	287.86
3000	477.175	138.85	1079.20	314.26

1° = 17.7 mils. 1 mil = 3.437 minutes. 1 minute = .291 mils.

TABLE IV

CONVERSION DATA FOR ENGLISH AND METRIC SYSTEMS

Approximate Values

1 millimeter = $\frac{1}{25}$ inch
1 centimeter = $\frac{3}{8}$ inch
1 decimeter = 4 inches
1 meter = $1\frac{1}{10}$ yards = 39.3685 inches (exact)
1 decameter = 33 feet
1 Kilometer = $\frac{5}{8}$ mile

	Linear	Square	Cubic
Inches : C'timeters	= 26 : 66	31 : 200	5 : 82
Yards : meters	= 82 : 75	61 : 51	85 : 65
Miles : kilometers	= 87 : 140	22 : 57	
Ounces : grammes	= 6 : 170	Cu. ft. : lbs. water	= 5 : 312
U. S. gals. : litres	= 14 : 53	U. S. gals. : lbs. water	= 3 : 25

Pounds : Kilogrammes = 75 : 34
Cubic feet : litres = 6 : 170

TABLE V

MIL DATA FOR MACHINE GUNNERS

As most of the results in the following did not come out in even mils, figures are given to the nearest even mil.

Vickers, Model 1917—Mark 4 Tripod

One tooth traversing arc	12.5 mils
One turn tripod elevating handwheel	43 "
One turn sight elevating screw	1— mil
One division windage	1+ "

With chin against safety catch:

Width of front sight cover outside subtends	17— mils
Width of front sight cover inside subtends	12 "
Height of front sight cover outside subtends	14+ "
Height of front sight cover inside subtends	12— "

Colt, 1917

One turn mount elevating handwheel	63+ mils
One turn sight elevating screw	1 mil

With chin against grip:

Width of front sight cover outside subtends	14 mils
Width of front sight cover inside subtends	11+ "
Width of front sight base proper subtends	5 "
Height of front sight proper subtends	5 "

Benet-Mercie

One turn elevating mechanism handwheel	16 mils
One-eighth turn elevating mechanism handwheel	2 "
One turn sight elevating screw	1 mil

In firing position:

Width front sight cover	12 mils
Height front sight cover	5 "

Lewis, American Model, Cal. 30

One turn sight elevating screw	7— mils
Three notches sight elevating screw	1— mil

In firing position:

Width of front sight proper subtends	2+ mils
Height of front sight subtends	4— "
Width of front sight base subtends	9+ "
Width between front sight guards inside subtends	17+ "
Peep hole in rear sight subtends	30 "

Hotchkiss

One turn tripod elevating screw	53 mils
One division traverse	10 "

With chin against breech housing handle:

Width of front sight subtends	6+ mils
Height of front sight subtends	7— "
Width of rear sight head subtends	43— "
Width of rear sight notch subtends	7+ "
Depth of rear sight notch subtends	7— "

TABLE VI

TABLE OF DRIFT

Cal. 30 U. S. Ammunition 1906

Range Yards	Uncorrected Drift (Right) Feet	Range Yards	Uncorrected Drift (Right) Feet
1000	1	2000	12
1200	2	2200	17
1400	4	2400	22
1600	6	2600	28
1800	9	2800	36

TABLE VII

FIRE TABLE

U. S. Rifle Cal. 30. Model 1903, Model 1905 Sight and 1906 Ammunition. Initial Velocity 2700 ft. per second

Range (Yards)	Time of Flight (Computed) (Seconds)	Range (Yards)	Time of Flight (Computed) (Seconds)
100	0.116	1700	4.189
200	0.243	1800	4.572
300	0.384	1900	4.977
400	0.693	2000	5.394
500	0.709	2100	5.827
600	0.899	2200	6.277
700	1.108	2300	6.744
800	1.340	2400	7.182
900	1.593	2500	7.734
1000	1.864	2600	8.258
1100	2.153	2700	8.803
1200	2.458	2800	9.370
1300	2.776	2900	9.962
1400	3.108	3000	10.577
1500	3.453	3100	11,219
1600	3.813		

TABLE VIII

GRAVITATION AND THE LAW OF FALLING BODIES AS APPLIED TO THE TRAJECTORY CURVE

The earth's attraction is measured by the increase in the velocity of a falling body which that attraction produces in a second of time. This quantity is called "G" or 32 feet approximately.

This means that when a body starts to fall its velocity at the beginning is zero, and at the end of the first second is "G" or 32 feet and for each second of fall the object *gains* velocity at the rate of 32 feet per second.

The velocity of any falling body at any instant equals "G" multiplied by the number of seconds the body has been falling.

From this fundamental law of motion of falling bodies we get the following formulas:

V = Velocity at any point in feet per second.
H = The distance through which the body has fallen from rest to the given instant.
T = The duration of the time of fall in seconds.

Then

$$V^2 = 2\,G\,H$$

as

$$V = G\,T,\ H = \tfrac{1}{2}G\,T^2$$

or

$$H = 16\,T^2$$

From the above relations it is seen that the time of flight of a bullet determines the amount it will drop before reaching the target and therefore the amount which it is necessary to direct the bullet above it to counter-act the drop.

The angle necessary to elevate the gun in order to counter-act the drop in attaining a given range, is the angle of departure.

The graduations of the rear sight are therefore based upon the angle of departure.

The highest point a bullet attains in its flight for a given range or in other words, the maximum ordinate for any trajectory is obtained by the following rule:

The maximum ordinate in feet equals the square of double the time of flight.

Any ordinate in mils of any trajectory is equal to the difference between the angle of departure of the trajectory

in mils, and the angle of departure (in mils) of a range equal to the horizontal distance to the ordinate.

The height of the ordinate in yards is the height of the ordinate in mils multiplied by the horizontal distance in yards to the ordinate; divided by 1000.

Dividing by 1000 is the same as pointing off the last 3 figures in the answer.

Note. The above discussion which may appear irrelevant and useless, has been inserted in this text for the purpose of a better understanding of machine gun ballistics and trajectory curves. The same may also be said of the definition of drift in the fore part of the book and the table of the time of flight of the bullet. While of no practical use whatever, this information enables one to more thoroughly grasp the principles upon which all sighting and firing must be based. Such matter is usually omitted from hand-books but its insertion here can do no harm and may do some good. Therefore it has been presented here for those who wish it and all others may leave it alone.

TABLE IX. MISCELLANEOUS DATA OF INTEREST TO THE MACHINE GUNNER

Machine Guns and Automatic Rifles of the Various Belligerents	Method of Operation	Method of Cooling	Weight	Caliber	Initial Velocity	Rounds per Minute	Weight of Tripod	Rounds per Clip or Belt	Model	Nation by Whom Used
Name of Gun					Ft. per Second		Pounds			
Browning—Heavy....	Recoil	Water	28	.30″	2641	600	37	250	1918	U. S.
Browning—Light.....	Gas	Air	18	.30″	2640	600	....	20	1918	U. S.
Berthier M. R........	Gas	Air	19.8	.30″	2641	500	....	30	1918	U. S.
Benet-Mercie A. M. R.	Gas	Air	30	.30″	2650	550	1½	30	1909	U. S.
Chauchat M. R......	Recoil	Air	19.5	.30″ 8mm	....	300	....	20	1915	U. S. & France
Colt A. M. G........	Gas	Air	35	.30″	2663	430	56.5	250	1914	U. S.
Lewis Machine Gun..	Gas	Air	25¼ 26½	.303″ .30″	2651	500	*6.0 1½	47	1916	English & U. S.
Madsen Auto. Rifle...	Recoil	Air	18	7mm	2096	375	....	20	1903	
Madsen—Aero.......	Recoil	Air	12	....	....	....	....	20	1914	
Marlin—Aero........	Gas	Air	25	.30″	....	500	....	250	1918	U. S.
Maxim A. M. G......	Recoil	Water	64½	.30″ 7.9mm	....	440	80	250	1904	U. S. & Germany
Vickers Machine Gun.	Recoil	Water	29.7	.30″	2648	500	37	250	1915	U. S.
Vickers—Light.......	Recoil	Air	22	.30″	....	600	....	250	1918	U. S.
Hotchkiss M. R	Gas	Air	52.9	8mm .30″	2733	400	50.7	30	1914	French & U. S.

**Note.* Lewis Bipod .303 Model 1916 = 6 lbs.; .30 Model 1917 = 1½ lbs.

TABLE X

PENETRATION OF RIFLE BULLET

Engineer Field Manual

	Inches	
	200 Yards	600 Yards
Commercial Steel	0.30	0.10
1-inch broken stone, gravel	4.80	4.30
Hard coal between 1-inch boards	9.00	7.00
Brick masonry, cement†	2.20	1.20
Brick masonry, lime†	2.40	1.20
Sand, dry	9.00	12.00
Concrete, 1-3-5	3.00	2.00
Oak	27.00	12.00
Sand, wet	15.00	13.00
Pine	26.00	13.00
Earth, loam	20.00	16.00
Grease clay	60.00	32.00

†For single shot: 150 rounds concentrated at one spot will break a 9-inch wall at 200 yards.

Armor-piercing Bullets versus First-class Special Steel Armor Plates

Penetrations have been obtained at following ranges for following thicknesses of armor plate (normal impact):

Thickness of Plate in Inches	Range in Yards
0.05	2,000
.10	1,500
.15	1,000
.20	500
.25	400
.30	320
.35	200
.45	About 25

The bullets were special armor piercing bullets such as are being used by European belligerents for attacking trench shields, armored automobiles and aircraft, etc. The armor plate was of the first quality special high carbon steel. One-half inch special armor plate is probably the minimum that will resist all bullets at short range.

Ordinary Service Bullets (Springfield Caliber .30) versus Special Steel Armor Plates

(Same plate as above.)

In connection with the above tests, it was found that the ordinary service bullet will not penetrate a ¼-inch special armor plate at 10 yards range.

MACHINE GUN FIRE CONTROL

By Capt. Glenn P. Wilhelm, 4th U. S. Infantry

A complete text book, fully illustrated, of the use of the Mil system in the control of Machine Gun Fire with particular reference to modern trench warfare methods.

For beginners as well as experts. All terms are fully defined and illustrated. Tells how to calculate ranges and elevations from contoured maps for Indirect Fire. Valuable tables are in the book to be found in no other publication.

Do you know how to elevate and direct your Machine Gun in order to safely fire over your own troops at an invisible enemy trench over a hill?

Do you know what elevation and direction to use on your Machine Gun in order that you may fire over your own front line trenches and search with long range fire enemy supply dumps and communications on the reverse slope of a hill?

This book tells you how.

THE MILOMETER OR BALLISTIC COMPUTING SLIDE RULE

Have you a natural dislike for mathematical data required for indirect fire? If so, you need this book which is furnished with a most ingenious fire control slide rule that will mechanically figure ranges, measure angles, determine widths, calculate any sight setting or elevation for direct fire, indirect fire, searching fire, combined sights, overhead fire, barrage fire, night firing, etc., and determine all manner of fire control and map problems.

Will do all any mil scale will do and more.

Will do all any fire control computing slide rule will do and more.

The Milometer is constructed on the usual rectangular slide rule design and is simple in appearance and operation.

EXCLUSIVE FEATURES

Common or Mannheim style of slide rule similar to majority of slide rules.

Mil and trajectory scales are on the same side of rule.

Direct reading scales for angles of departure and angles of fall.

Six-inch scale in inches and tenths of inches.

Twelve-inch scale in inches and sixteenths inches.

Fifteen-centimeter scale in millimeters.

Least reading on mil scale is two mils, by estimation one mil.

Rectangular protractor reading to one degree.

Fourteen formulas for range, mil scale and indirect fire.

Mechanically converts metric units to English and vice versa, with the conversion indexes on the rule.

Made of heavy white celluloid. Graduations cannot be obliterated by wear or soiling as the face of the rule is protected by transparent celluloid.

Each rule is equipped with a catgut cord conveniently located for use with either the mil scale, the protractor or as a slope board.

Price $2.50, includes Sliding Rule

Price $1.75 for Book or Rule separate

Remit by Registered Letter, Money Order or Bank Draft

Published and For Sale by

EDWARD C. McKAY

409 SWETLAND BUILDING - - - CLEVELAND, OHIO